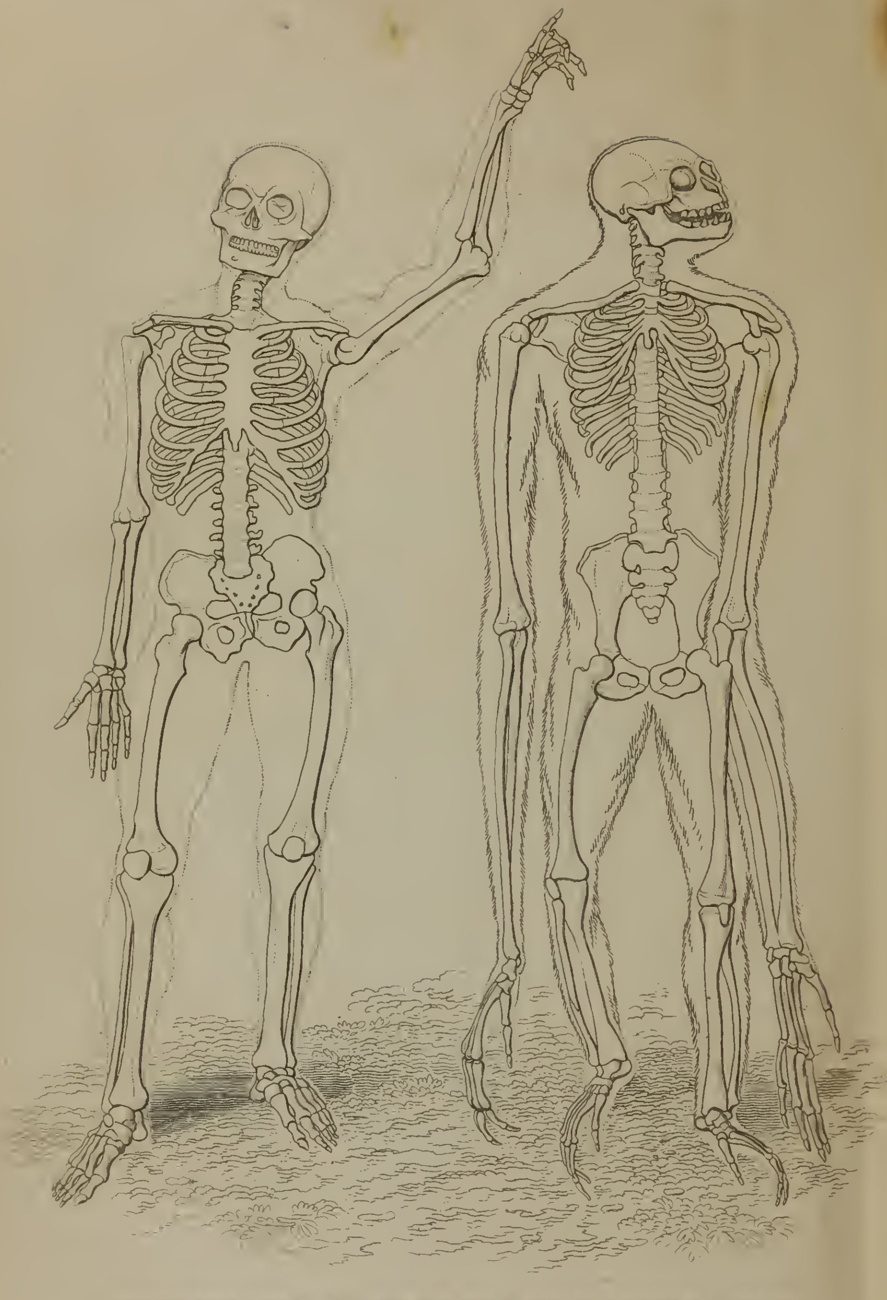

AN

ELEMENTARY TREATISE

ON

HUMAN PHYSIOLOGY,

[illegible]

PRÉCIS ÉLÉMENTAIRE DE PHYSIOLOGIE.

BY

F. MAGENDIE.

[illegible]

[illegible]

[illegible]

BY JOHN REVERE, M.D.

[illegible]

NEW YORK.

[illegible]

1843.

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ELEMENTARY TREATISE

ON

HUMAN PHYSIOLOGY,

ON THE BASIS OF THE

PRÉCIS ELÉMENTAIRE DE PHYSIOLOGIE.

PAR F. MAGENDIE,

MEMBRE DE L'INSTITUTE DE FRANCE, &c., &c., &c.

FIFTH EDITION. 1838.

TRANSLATED, ENLARGED, AND ILLUSTRATED WITH DIAGRAMS AND CUTS. ESPECIALLY DESIGNED FOR THE USE OF STUDENTS OF MEDICINE.

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INTRODUCTION.

In the year 1822, the undersigned published a translation of "The Summary of Physiology" by M. Magendie. It was most favourably received by the profession, two large editions having been rapidly disposed of. For reasons over which the editor had no control, and which are at present unimportant to the public, no new edition of this translation has appeared since the second. The original work, however, has gone through several large editions with increasing reputation, and now occupies the highest rank among standard works, not only in France, but throughout Europe. Since the period alluded to, the science of Physiology has undergone, on many points, a complete revolution, in the accomplishment of which M. Magendie has acted a very conspicuous part. Since the death of Sir Charles Bell, perhaps there is no physiologist who stands so pre-eminent as an original observer and inquirer, or who has contributed so much to the present improved state of the science by his individual efforts. In facility in experimenting upon living animals, and extended opportunities of observation, no one has surpassed him; while, through a long professional career, his attention has been chiefly devoted to physiological inquiries.

There is one excellence which constitutes a predominant feature in his system of Physiology that cannot be estimated too highly by the student of medicine. I allude to the severe system of induction that he has pursued, excluding those imaginative and speculative views, which rather belong to metaphysics than physiology. The work is also remarkable for the conciseness and perspicuity of its style, the clearness of its descriptions, and the admirable arrangement of its matter.

The present work is a translation of the fifth and last edition of the "*Précis Elémentaire de Physiologie*," in which the science is brought down to the present time. It is not, like many modern systems, merely eclectic, or a compilation of the experiments and doctrines of others. On the contrary, all the important questions discussed, if not originally proposed and investigated by the author, have been thoroughly examined and experimented

upon by him. His observations, therefore, on all these important subjects, carry with them great interest and weight derived from these investigations.

It has been the purpose of the translator and editor, while faithfully adhering to the spirit of the author, to endeavour, as far as can be done consistently with this, to strip the work of its foreign costume, and *naturalize* it to our language. He has added a large number of diagrams and pictorial illustrations of the different organs and structures, taken from the highest and most recent authorities, in the hope of rendering clearer to the student of medicine the observations and reasonings on their functions. He has also made a number of additions on subjects which he thought had been passed over in too general a manner in the original work of M. Magendie. The additional matter is indicated by brackets. In a word, it has been his aim to present a system of human physiology which shall exhibit in a clear and intelligible manner the actual state of the science, and adapted to the use of students of medicine in the United States.

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PREFACE.

The natural sciences, like history, have had their fabulous period. Astronomy commenced in astrology; chemistry was not long since alchemy; and medicine but a combination of absurd hypotheses. Strange condition of the human mind, which seems to require that it should long exercise itself in error before it dare approach the truth! Such were the natural sciences before the seventeenth century, when Galileo appeared, and discovered to mankind that to understand nature, it is not enough to IMAGINE or BELIEVE, as the ancients supposed, but to OBSERVE, and, above all, to INQUIRE by EXPERIMENTS. This was the spirit that inspired the labours of the immortal Newton, and of those men of genius, who, during the last century, annihilated the antique doctrines of the four elements, and replaced them by the pneumatic theory. The same spirit animates the natural philosophers and chemists of the present day; guides them in their ingenious and useful researches, and forms between them a new and indissoluble bond.

Glory, then, to Galileo! In demonstrating by memorable example the immense advantages of observation and experiment; in turning the human mind from the false direction where its powers had exhausted themselves for ages in vain efforts, he really laid the foundation of the physical sciences; of those sciences which elevate the dignity of man, increase incessantly his power, secure the wealth and happiness of nations, place our civilization above that of all preceding ages, and open to posterity a brilliant future.

Would that I could say that PHYSIOLOGY, in the language of Bacon, THE SCIENCE OF OURSELVES, has pursued the same course, and undergone the same metamorphosis as the physical sciences. But, unfortunately, this is not the case; Physiology is still, in the minds of many, and in some of our books, a mere work of the imagination; it has its different creeds, and opposite and contending sects; it admits the existence of fabulous beings, who, like the pagan gods, preside over the phenomena of life; the authority of authors calling themselves infallible is invoked; in a word, it may be said to be the framework of a religion strangely filled with scientific terms.

Still there are men who have successfully applied the experimental method to the study of life; great discoveries have been the fruits of their efforts; science is enriched—extended, but its general form, its method of investigation, remains the same; and by the side of the phenomena of the CIRCULATION OF THE BLOOD, of RESPIRATION, MUSCULAR CONTRACTION, &c., are placed, in the

same line, such metaphors as the ORGANIC SENSIBILITY, or such offspring of the imagination as THE NERVOUS FLUID, or such unintelligible expressions as the VITAL FORCE OF PRINCIPLE.

The object of this work is to endeavour to change the state of Physiology in this respect; to lead it back to positive facts; in one word, to impart to that beautiful science the happy renovation which has taken place in the physical sciences. I am not ignorant of the difficulties before me; I fully appreciate them; they belong to the nature of man, and are but physiological phenomena.

Numerous prejudices separate Physiology at present from the exact sciences: extreme repugnance to experiments on living animals; the pretended impossibility of applying these deductions to man; the almost absolute ignorance as to the method of proceeding so as to attain truth; attachment to old ideas, always sustained by carelessness and indolence; a kind of passion among men to cling to old errors, even contrary to their own interests—these are some of the obstacles which it will be necessary to surmount. They are certainly great, but, trusting to the gentle but steady influence of truth, I cannot doubt that success is not remote. Already the hypothesis of the organic functions is no longer received with the same favour; and to a work on speculative physiology, *some* experiments are indispensable. The belief, so injurious and absurd, that physical laws have no influence on living bodies, has no longer the same force. The choicer spirits begin to admit that there may be in the living animal different orders of phenomena, and that acts simply physical do not exclude actions purely vital. It is no longer doubted that researches made upon animals apply with remarkable precision to the phenomena of life in man; the vivid light that recent experiments relative to the nervous functions have thrown upon pathology, has removed all uncertainty on this point.

But what proves better than anything I can say, how much the utility of physiological experiments are perceived, is the great number of persons who have engaged in these investigations; and also the rapidity with which important discoveries, even the most unexpected, have succeeded each other, so as to make the science of life a new science. In a few years, Physiology, so intimately connected with the physical sciences, can no longer advance but by their aid. It will acquire the vigour of their method, the precision of their language, and the certainty of their results. In raising itself thus, it will be removed from that ignorant and vain crowd always ready to repel truth and protect error. Medicine, which is but THE PHYSIOLOGY OF MAN DISEASED, will not fail to follow in the same direction and attain the same height. We shall then see those erroneous explanations disappear which have misled the best minds, and disfigured it so long.

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CHAPTER I.

PRELIMINARY OBSERVATIONS.

Physiology, or Biology, is that vast natural science which studies life wherever it exists, and investigates its general characters. It may be divided into *Vegetable Physiology*, which is confined to vegetables; *Comparative Physiology*, which treats of animals; and Human Physiology, the particular object of which is man. It is of this last that we propose to treat in the following work.

Of Substances and their Divisions.

The term substance, or body, may be applied to everything which is capable of acting upon our senses. Substances are divided into ponderable and imponderable. The first are those which act on several of our senses, and the existence of which is therefore clearly demonstrable, as solid, liquid, and gaseous bodies. The second are those which do not act in general upon more than one of our senses, the existence of which has not been demonstrated, and which may, perhaps, be but a modification of other bodies: such are caloric, light, the electric and magnetic fluids. Ponderable substances are endued with common or general, and particular or secondary properties. The general properties of substances are extension, divisibility, impenetrability, and mobility. A ponderable body possesses always these four properties united. The secondary properties are different in different bodies, such as hardness, porosity, elasticity, fluidity, &c.; they, together with the general properties, constitute the state of the body. It is in acquiring or losing these secondary properties that bodies change their state: *e. g.*, water may exist under the form of ice, liquid, or vapour, although it is still the same body. To appear successively under these three different forms, it is only necessary that they should acquire or lose some one of these secondary properties.

Substances are simple or compound. Simple substances occur rarely in nature, but are almost always the product of art; indeed, they are only called simple because no artificial means have been discovered of decomposing them. The following are the names of bodies at present considered simple, viz., oxygen, chlorine,

iodine, fluorine, sulphur, hydrogen, aluminium, yttrium, glucinium, magnesium, zinc, iron, tin, arsenic, molybdenum, chromium, tungstenium, antimony, uranium, cerium, cobalt, titanium, bismuth, copper, tellurium, nickel, lead, mercury, osmium, silver, rhodium, palladium, gold, platina, iridium, borium, carbon, phosphorus, azote, silicium, zirconium, columbium, strontium, barium, sodium, potassium, manganesium, calcium, selenium, lithium, cadmium, thorinium, bromium.

Compound substances are found everywhere; they form the mass of this globe, and of almost everything which we see upon its surface. There are some substances, the composition of which does not undergo any spontaneous change; there are others, a change in the composition of which is constantly taking place. This constitutes a very important difference in bodies; they are thus very naturally divided into two classes. Those substances, the composition of which remain constantly the same, are called *dead, inert, inorganic bodies;* those, on the other hand, the elements of which are continually varying, are called *living, organized bodies.*

The custom has long been established in elementary books of pointing out the difference between organic and inorganic bodies. In conformity to this usage, it may be remarked, that organic and inorganic bodies differ from each other in the three following respects, viz.: first, in form; second, in composition; third, in the laws which govern their changes of state. The following table exhibits the most remarkable differences:

Differences between Dead Inorganic and Living Organized Bodies.

	FORM.		
Inorganic bodies.	Form angular. Volume indeterminate.	Form rounded. Volume determinate.	Living bodies.
	COMPOSITION.		
Inorganic bodies.	Sometimes simple. Rarely formed of more than three elements. Constant. Each part can exist independent of the rest. Capable of being decomposed and restored.	Never simple. Having at least four elements, often eight or ten. Variable. Each part more or less dependant on the rest. Capable of being decomposed, but not of being restored.	Living bodies.
	LAWS WHICH GOVERN THEM.		
Inorganic bodies.	Entirely submissive to the laws of attraction and chemical affinity.	Subject to attraction and chemical affinity, but presenting many phenomena that cannot be referred to either of these forces.	Living bodies.

Among these characteristics there are numerous exceptions, and some which may hereafter disappear. For example, it is said that living bodies may be decomposed, but cannot be recomposed. Nevertheless, chemistry has succeeded in reproducing certain combinations which are only found in organized bodies. It is possible it may go still farther.

Living bodies arrange themselves into two classes; the one includes vegetables and the other animals.

Differences between Vegetables and Animals.

VEGETABLES.	ANIMALS.
Are fixed to the soil.	Have the power of locomotion.
Have carbon as the principal base of their composition.	Have azote for the base of their composition.
Composed of four or five elements.	Often composed of eight or ten elements.
Receive from around them their aliment ready prepared.	Are compelled to act upon their aliment to render it suitable to nourish them.

Animals are extremely numerous and diversified. They have been divided into classes, according to their most striking differences. This arrangement of animals is founded on their forms and superficial characters. When we become better acquainted with their functions and physiological phenomena, it will probably undergo numerous modifications. Man is placed in the class of mammiferous animals, a class made up of a great number of divisions, comprehending different animals.

Man, zoologically speaking, then, is one of the mammiferi; he presents all the characters of this class of animals, but is distinguished from them by some striking peculiarities, and especially by his intelligence and the superiority of his instincts. Nevertheless, in these respects there are great differences among men. These differences depend upon the different varieties of the human species, and the faculties of individuals of the same variety. There are races of men who differ little from other animals. Physiology thus far, if the expression be allowable, has been especially concerned with the variety of which we form a part. It would be desirable to treat generally of man, but this supposes an acquaintance with each variety, which is not at present practicable.

Structure of the Body of Man.

If we would arrive at a knowledge of the phenomena that living man presents, we must first form some idea of the construction of his body, and of the different substances which compose it.

The most superficial examination shows that the bodies of all animals, of every living being, and in this respect that of man does not differ, is composed of solids and fluids. The proportion of fluids greatly exceeds that of the solids. If the body of a man weighing 120 pounds be exposed to causes which drive off the fluids, it may be reduced to 10 pounds. This depreciation may be carried still farther. If the residue be subjected to calcination, it will be still much more reduced, perhaps to one pound. At the commencement of its existence, the animal consists entirely of liquid.

In the living and developed animal, the fluids are, for the most part, combined or simply imbibed into the solid parts, of which they determine the volume, form, and general physical properties. Another part of the fluids is contained either in canals, in which

they move, or in cavities more or less spacious, in which they remain. Until lately, little has been known of the union of the fluids and solids, but we have reason to hope much in this respect from the rapid progress of organic chemistry.

Solids of the Human Body.

The solids affect a great number of different forms; there are those solids which form the organs, the tissues, the parenchyma; their mechanical analysis shows that they may be reduced to small fibres, lamellæ, or small grains. In looking at them through the microscope, they appear like assemblages of small molecules, the dimensions of which have been estimated at about the 300th part of one millimetre.

If the progress of the mind in physiological studies had been guided by reason, the first step would have been to ascertain precisely the physical and chemical properties of the different tissues and fluids which compose our bodies. This point being settled, it would have been much easier to distinguish and study the properties which life imparts or takes away from our elements. But this course has not been pursued; physics and chemistry have scarcely been referred to by physiologists; thus many injurious prejudices have been introduced at the very basis of the science. But our gratitude is due to Bichat for having made an attempt of this kind. Availing himself of the happy idea of the venerable Pinel respecting the distinction of the solid elements of the animal economy into systems, he founded general anatomy, and sought to recognise the physical and chemical properties of the organs, and of their elements. Unfortunately, at the epoch at which he wrote, he could only obtain superficial and inaccurate information. In this respect the science requires at present a complete renovation. Also, the following table, which presents a classification of the different tissues of the animal economy, notwithstanding the improvements it has undergone since the time of Bichat, can only be considered approximative and provisional.

* These visible molecules should not be confounded with the *atoms* or *particles* which, according to natural philosophers and chemists, form all bodies. The last are simple abstractions, convenient to explain many physical and chemical phenomena. In reality we know nothing of the intimate disposition of matter in bodies. It is beyond the ken of our senses, as the infusory animals, the globules of fluids, &c., were before the invention of the microscope. He who shall discover an instrument by which we may perceive the intimate arrangement of matter, will enrich the field of human knowledge, and immortalize himself.

The ancients believed that all the solids may be traced back to a simple fibre, which they supposed was formed of earth, oil, and iron. Haller, who admitted this idea, acknowledges that it is only perceptible to the mind's eye. *Invisibilis est ea fibra; sola acie mentis distinguimus.* This is equivalent to saying it did not exist at all, of which no one now doubts. The ancients, likewise, admitted secondary fibres, which they supposed were modifications of the simple fibre, as the nervous, muscular, parenchymatous, and osseous fibre. M. Chaussier has proposed to admit four kinds of fibres, viz., laminar, nervous, muscular, and albugineous.

Table of the Tissues of the Human Body.

1.	Systems.	Cellular.	
2.		Vascular	Arterial. Venous. Lymphatic.
3.		Nervous	Cerebral. Of the ganglions.
4.		Osseous.	
5.		Fibrous	Fibrous. Fibro-cartilaginous. Dermoid.
6.		Muscular	Voluntary. Involuntary.
7.		Erectile.	
8.		Mucous.	
9.		Serous.	
10.		Horny, or epidermic	Pilous. Epidermic.
11.		Parenchymatous.	Glandular.

These different tissues, with the fluids, compose the organs or instruments of life. When several organs tend to one common end, they may be called an *apparatus*. The number of these and their arrangement constitute the differences between animals.

Physical Properties of the Organs.

The examination of the physical properties of the organs shows that they possess most of those which belong to inorganic bodies; there are different degrees of hardness, from that of silex to great softness, elasticity, transparency, refrangibility, colours and forms extremely varied, &c. All these properties are important during life, which in many instances depend upon their integrity. Viewed in this relation, the human body offers many arrangements which leave no doubt of the necessity of a knowledge of natural philosophy to enable us to study life. It presents a curious and complicated optical instrument; an acoustic apparatus; an hydraulic machine most ingeniously arranged to circulate a fluid; a piece of mechanism admirable for the multiplicity of the pieces which compose it, its strength, and the diversity of the motions it is capable of executing, &c.

Among the physical properties of the organic tissues, there are some which merit special attention, because they are common to all the tissues, are kept in constant operation during life, and preside over many of the functions. It is the more important to point them out to the attention of beginners, as they are doubted by many physiologists. One of the most remarkable of these, and to which I not long since called the attention of physiologists, is the *property of imbibition*, which exists in all the tissues. If we place any liquid in contact with an organ, a membrane, or tissue, in a shorter or longer time the liquid will pass into the *areoles* of the organ or tissue, as it would have penetrated into the cells of a sponge or of a porous stone. The time required for the imbibition will depend on the nature of the liquid, its temperature, and the particular tissue, but in all the imbibition will take place. In this respect some of the tissues are true sponges, which absorb

promptly, as the serous membranes and small vessels; others resist for some time, as the epidermis.

This property belongs not only to animals, but to all organized beings; it exercises an evident influence on many of the phenomena of life. M. Dutrochet remarked a curious fact relative to imbibition; it is, that if a membrane be placed in contact at its opposite sides with two liquids having different degrees of viscidity, that the least viscid passes through the membrane and mixes with the most viscid, until its viscidity is much diminished. Then a part of the liquid, the viscidity of which is diminished, passes back through the membrane, and thus the two liquids acquire an equal degree of viscidity. M. Dutrochet called the first phenomena *endosmosis*, and the second *exosmosis*. These phenomena require farther examination; the author of this discovery has exaggerated its importance, and is engaged in suppositions which have turned him from the experimental course, that he should not have abandoned.

M. Chevreuil has made an interesting observation on the subject of imbibition. Several of our tissues owe their physical properties to the water they retain, or, rather, the water they have imbibed. If this water is removed, they change, and become unfit for the purposes which they fulfil during life. But they recover their properties as soon as they are brought in contact with the water, and it penetrates them. They may thus lose and recover a number of times their physical properties.

Another physical property to which physiologists have given little attention, is in respect to the membranes. The lamellæ which compose them are so arranged that gases traverse them with but little difficulty. If we take a bladder and fill it with pure hydrogen gas, and afterward leave it in contact with the atmosphere, in a short time the hydrogen will have lost its purity, and will be mixed with atmospheric air, which has penetrated into the bladder. The rapidity of this phenomenon depends upon the thickness and density of the bladder. This presides over one of the most useful acts of life, respiration; it remains after death.

There is still another physical property which our tissues and whole bodies possess, similar to inorganic substances. It is that of evaporation. Whenever we are placed under circumstances favourable to this process, it occurs precisely as in other bodies. The watery parts of the fluids pass off in vapour, the loss being proportioned to those conditions which favour evaporation. This physical *property* has so great an influence on certain animals that they die in a few instants if the evaporation of their liquids takes place with great rapidity.

Chemical Properties of the Organs.

In the operations going on in our bodies, we recognise numerous phenomena of a chemical nature. In the digestive apparatus we find certain arrangements analogous to those of the laboratory. The lungs may be considered a sort of apparatus of

combustion, where. by a simple contrivance, the combustible is burned slowly, so as to produce a uniform heat. If we examine the chemical composition of our bodies, we remark that it is formed of different *elements;* some similar to those of inorganic bodies, as water, carbonic acid, chlorures of sodium and calcium, and sometimes of compounds which are only met with in organic bodies.

Elements which enter into the Chemical Composition of the Organs.

Sixteen simple bodies or elements enter into the composition of animals. Other elements, under certain circumstances, may traverse the animal organism, but they do not remain long, or they become injurious.

Immediate Principles of the Body of Man.

These are divided into *azotic* and *non-azotic.*

The *azotic* principles are albumen, fibrine, gelatine, mucus, caseum, urea, uric acid, osmazome, the red colouring principle of the blood, the yellow colouring principle.

The *non-azotic principles* are oleine, steorine, the fatty matter of the brain and nerves, the acetic acid, the lactic acid, the oxalic acid, soracic acid, the sugar of milk and of diabetes, picromel, cholesterine, the colouring principles of the bile, and other liquids or solids which become coloured accidentally.

The immediate organic principles are, in general, formed of three or four elements: oxygen, azote, hydrogen, and carbon. The first three being gaseous in a free state, tend continually to abandon the solid form, and this tendency is much augmented by the natural temperature of the living body, and by the affinity which solicits the hydrogen and oxygen to unite to form water, and the oxygen and carbon to form carbonic acid, and the azote and hydrogen to produce ammonia. On the other hand, the carbon and hydrogen not finding in the organism sufficient oxygen to convert themselves into carbonic acid, these bodies have an evident tendency to absorb oxygen from the atmospheric air, and this disposition is increased by the high temperature of the body and the contact of water, which diminishes the cohesion of compounds, and thus favours new combinations. From these different causes results the long-known fact, that the dead animal body has a great tendency to decomposition, in consequence of the continual effort of these elements to return to their original condition, according to the general laws of nature.

Of the Fluids or Humours.

The fluids of animal bodies, especially man, greatly exceed the solid parts. In the adult, they are as nine to one. Professor Chaussier placed a body, weighing one hundred and twenty pounds, in an oven; after being allowed to dry for several days, it was found to be reduced to twelve pounds. It has been long

remarked, that dead bodies which have been found, after having been long buried in the burning sands of Arabia, have undergone an astonishing diminution of weight. The animal fluids are sometimes contained in vessels, in which they move with a greater or less degree of rapidity, sometimes in spaces called *areoles* or *vacuoles*, where they are deposited; at others they are placed in considerable cavities, where they remain for some time; lastly, in the greater number of instances they are imbibed into the solids, of which they become an essential part.

List of the Liquids or Humours of the Body.

1st. The Blood	The most important of all the fluids, from its quantity, its nature, its vital properties; the source of all the other humours, its loss leads immediately to death, and its alterations are followed by disorder of the functions.
2d. The Lymph	A sort of imperfect blood, found frequently in small quantity in a particular order of vessels; its uses but little known.
3d. The Cephalo-spinal Liquid .	This surrounds the central nervous system, and fills its cavities.
4th. The Aqueous and Vitreous Humours . . . . 5th. The Crystalline . . . 6th. The Pigmentum Nigrum .	Assist in vision by their physical properties.
7th. The Labyrinthine Liquor of the Ear	Use unknown.
8th. The Fat	Surrounds the organs, and protects them by their physical properties.
9th. The Marrow . . .	Fills the cavities of the bones.
10th. The Synovia . . .	Favours motion by diminishing the friction of the movable surfaces in contact.
11th. Serosity of the Cellular Tissue	Use analogous to that of the synovia.
12th. Serosity of the Serous Membranes	Lubricates the surface of these membranes.
13th. The Liquid which evaporates from the Surface of the Skin, or the Sweat	Contributes to maintain the equable temperature of the body.
14th. The Unctuous Humour of the Skin	Favours its contact with foreign bodies.
15th. Mucus	Covers the mucous membranes, and protects from injurious contact.
16th. The Gastric Juice . .	Dissolves the aliments in the stomach.
17th. The Pulmonary Transpiration	Concurs in respiration.
18th. The Liquid that fills the cells of the Thymus . . 19th. The Liquid of the Thyroid Body . . . . 20th. The Liquid that fills the Capsula Renales . . .	Uses unknown.
21st. *Chassie*	Facilitates the motions of the eyelids and eyes.
22d. The Cerumen . . .	Protects the auditory passage.
23d. The Humour at the Roots of the Hair	Preserves their flexibility.
24th. The Sebaceous Humour on the external surface of the Organs of Generation . .	Favours the friction, and opposes the pressure which the genital organs undergo.
25th. The Tears . . .	Protect the eye, and are means of expression.
26th. The Bile . . . . 27th. The Pancreatic Juice ,	Concur in digestion.
28th. The Urine . . .	The residue of the chemical operations of the body.
29th. The Chyle . . .	Fluid nutritive extract of the aliments.

All these liquids, and some others not mentioned, are common to both sexes.

The fluids peculiar to man are,

1st. The Prostatic Humour .	Contributes to fecundation.
2d. The Fluids of the Sub-Prostate Glands	Uses unknown.
3d. The Semen	Fecundating fluid.

The fluids peculiar to women are,

1st. The Milk	To nourish the infant.
2d. The Fluid of the Vesicles of the Ovaria	Useful in generation.
3d. The Liquid of the Corpora Lutea	Useful in generation.
4th. " " Chorion .	Useful in generation.
5th. " " Amnion .	Useful in generation.
6th. " " Umbilical Vesicle	Useful in generation.

The physical and chemical properties of the fluids are very various. Many resemble each other, but no two are precisely alike. At all times, great importance has been attached to a methodical arrangement of them, and we find that different classifications have been adopted, according to the prevailing doctrines of the schools at different periods. Thus, the ancients, who laid great emphasis on the influence of the four elements in the operations of Nature, asserted that there were four principal humours in the body, viz., the blood, the lymph, the yellow, and the black bile; and that these four humours corresponded to the four elements, the four seasons of the year, the four parts of the day, and the four temperaments.

In more modern times, other divisions have been substituted for this classification of the ancients. Thus, they were at one time divided into three classes, viz., 1st, the chyme and chyle; 2d, the blood; 3d, the humours secreted from the blood. Some authors have thought it sufficient to arrange them into two classes: 1st, fluids which are useful as aliments; 2d, those which are useless in this respect. The first are called *recrementitial*, that is, humours which, after their formation, are destined to nourish the body; the second, *excrementitial*, or those which are thrown out of the economy; those humours which participate in these two characters have, for this reason, received the appellation of *excremento-recrementitial.* Chemists have lately endeavoured to classify the humours according to their peculiar nature; as the albuminous, fibrous, and aqueous humours, &c. But the classification of Professor Chaussier will be found to be the best. This has no regard to the nature of the fluids, or the uses to which they are destined, but is founded on the mode of their formation, the only character which remains always the same.

The following is his classification:

1st. The Blood.

2d. The Lymph.

3d. Perspiratory fluids, which comprehend the cutaneous transpiration; the transpiration of the mucous, serous, synovial, cellular, adipose, and medullary membranes, the interior of the thyroid thymus, the eye and ear.

4th. The follicular fluids; the fatty humour of the skin, the sebaceous humour of the eyelids, the mucus of the glands and fol-

licles of the tonsils, the cordia and parts about the arms and prostate, &c.

5th. The tears, saliva, pancreatic juice, bile, urine, the fluid of the glands of Cowper, semen, milk, of the capsulæ renales, the mammæ, and the testicles in new-born children.

6th. The chyme and chyle.

But the number of the humours is not so great that it is necessary to classify them. There is no difficulty in studying them separately. When once known individually, all classification becomes superfluous.

Physical Properties of the Fluids.

These are of considerable importance: those to which we have already referred are *viscidity*, *transparency*, *colour*, *odour*, &c. The viscid fluids are found wherever there are membranes to be preserved, friction to be diminished, and polished surfaces to be lubricated.

Transparency is especially found in the fluids of the organ destined to act on light. Many other fluids present this character to a greater or less degree.

The colours of the fluids vary but little; many of them are colourless.

Red of different tints, yellow, and black are the chief colours; even these result from two colouring matters, which, by their different modifications, produce all the other shades.

The odours of the fluids are very various.

Certain fluids present to the microscope a remarkable appearance; there are myriads of globules of a regular form and constant size. These globules are particularly met in the blood, lymph, chyle, and milk. The semen, when examined by the microscope, often exhibits a great number of minute animals, which move with great agility. But the presence of these singular beings is far from being as uniform as the globules of which we have spoken. They are only observed during certain periods of life and in health.

Chemical Properties of the Fluids.

The chemical qualities of the fluids are interesting to the physiologist. Many of the important vital actions depend immediately on these properties. Unfortunately, this part of the science is at present but little advanced; nevertheless, chemistry has furnished some useful information on this subject. We know that the composition of the fluids does not differ essentially from the solids. There are the same immediate principles and the same elements. If we drive off by evaporation a part of the water which many of the fluids contain, we obtain a semi-solidified mass, which has a great analogy in its composition with the true solids. This is not surprising, as in the living body the fluids are continually transformed into solids, and the solids into fluids. Most of the fluids exhale carbonic acid, and absorb oxygen from the air. Gen-

erally speaking, the fluids have a stronger tendency to decomposition than the solids. The immediate principles of the fluids also contain more azote, or caseum and urea, which are most rapidly decomposed.

Vital Properties.

Besides the chemical and physical properties of the solids and fluids, we also witness many phenomena not observed in inorganic matter, which constitute the essential characters of life. It would have been wise to have studied each of these phenomena separately, and to have thus acquired a precise notion of the special attributes of living organized bodies. But to obtain such a result, which would be capable of so many useful applications, it would be necessary to separate carefully in the living being that which is chemical or physical from that which is purely vital. Now this distinction has always been found impracticable, from the imperfection of our means of physical analysis. Even at the present time, when these means have acquired a greater degree of certainty and precision than at any former period, this distinction would be found extremely difficult, and would require for its execution a mind of a peculiar cast. But this course has not been adopted. There have been established, or, rather, *imagined*, certain vital properties, and it has been consequently affirmed that living bodies are in a perpetual struggle with the general laws of Nature; an idea inexpressibly absurd. That the ancients should have believed that such a struggle existed between the laws which govern the *microcosm* or little world, and the *macrocosm* or universe, is not surprising, when we recollect their ignorance of both organic and inorganic bodies. But now that the physical sciences have become so much improved, and made us acquainted with many very important laws of Nature, we perceive that these laws exert an evident influence upon animals. It is true that the living organs present phenomena which cannot be explained by mere physical laws, but it does not follow that they are opposed to each other; that there should be, for example, any opposition between sensibility and gravity, or between contractility and chemical affinity. These things are only different, not contrary to each other.

The vital properties, as generally admitted, have received different names.

1st. *Organic Sensibility*, nutritive, vegetative, and molecular.

2d. *Organic Contractility*, insensible, nutritive, and fibrillous, tone, tonicity.

3d. *Cerebral Sensibility*, animal, perceptive, &c.

4th. *Sensible organic Contractility*, irritability, vermicular motion.

5th. *Voluntary Contractility*, animal, of relation, &c.

Of these properties, some are considered common to all living bodies, others peculiar to certain parts of animals.

If they existed, the first only would deserve the name of *vital*

properties, inasmuch as they are characteristic of life wherever it is found. But many of these properties have no real existence; they have been *imagined* by physiologists, to enable them to explain phenomena beyond the reach of our senses, and, consequently, unknown. Our organs nourish themselves, but we are ignorant of the mode by which this vital act is accomplished. To become acquainted with it, it would be necessary to make many experiments, and to invent instruments which would subject to our examination things that are beyond the cognizance of our senses. The substitution of a *fiction* has been found more simple and easy. "Thus it is said the organs are composed of molecules, which are sensible (a mere gratuitous supposition); they distinguish, in the nutritious fluids which are presented to them, the elements which are fitted to repair their waste." Thus it appears that these molecules are endued, not only with sensibility, but discernment. But, in supposing that the molecules are capable of discerning the materials suitable to repair their waste, but half the phenomena is explained; it is also necessary that they should appropriate these materials. It has been attempted to remove this difficulty by the supposition of *insensible contractility;* but it is not easy to imagine by what sort of motion a molecule can seize upon the nutritive materials. Who does not see, in this little history, a mere metaphor of the history of an animal or of man? It is the *anthropomorphism* of the philosophers applied to molecules. The most curious part of it is, that the mind can rest satisfied with such mystification.

This is not all, the romance is pushed still farther: it is necessary to explain diseases which are an *exaltation*, or *weakening* or *perturbation* of the vital properties; hence *therapeutics*, the object of which is *to restore the vital properties to their normal type.* This is the foundation of systematic medicine. The student of medicine knows no way of avoiding this: the only way to do so is to learn early to say to himself, *I do not know;* this is the first step towards discovering the truth.

The other vital properties are peculiar to certain animals, or, perhaps, to some part of them; such is *sensible organic contractility*, as seen in the heart, alimentary canal, bladder, &c., but which is not observed in other parts of the economy.

Cerebral or *animal sensibility*, according to Bichat, as well as *voluntary contractility*, can only be accounted among the number of vital properties by an abuse of terms. It is evident that these are the functions or the results of the actions of several organs, which have one common end. We shall say nothing of *the force of vital resistance*, *vital affinity*, *caloricity*, &c., because these pretended properties, though proposed by men of ability, have not excited much attention among physiologists, and, besides, have not more reality than most of those of which we have spoken.

The doctrine of the vital properties have not, fortunately, been applied to the fluids, though they are admitted to possess life. A much more philosophical method has been pursued with respect

to them; for it was not admitted that they were endowed with life until this was proved. Thus their vitality has been inferred from their preserving their fluidity while they remain in certain parts of the living body; the plastic powers of some, and their capacity to evolve caloric. These are the principal phenomena which, according to some modern physiologists, indicate the life of the fluids. But only the blood, lymph, chyle, and a few others of the fluids destined to nutrition, present these characters. The excrementitial fluids, as the bile, urine, cutaneous transpiration, &c., do not possess these qualities; hence, what is called the vitality of the fluids does not exist in the latter.

Causes of the Phenomena peculiar to Living Bodies.

From the earliest antiquity, it has been observed that the greater number of phenomena which take place in living bodies are essentially different from those that occur in dead, inorganic matter. One particular cause has been assigned to explain the phenomena observed in living bodies. This cause has received different names. It was denominated by Hippocrates, φυσις (Nature); by Aristotle, *moving and generative principle;* by Boerhaave, *impetum faciens;* by Van Helmont, *archea;* by Staal, *soul;* others, again, have called it *vis insita, vis vitæ,* &c. M. Chaussier, in his learned lectures, and in his synopsis of the characters of vital power, has adopted the name "*force vitale.*"* It is not worth while to endeavour to deceive ourselves by this expression, "*force vitale,*" or vital power. It does not and cannot mean anything else than the *unknown cause* of vital phenomena.

But what signifies all these expressions? They must have one of two meanings: either that of entities, to which belong the power of producing vital phenomena; but, in supposing this, do we not resemble savages, who, after having rudely sculptured a stone, call it a God? Or we assert that these words, *force vitale,* designate the unknown, and, perhaps, incomprehensible cause or causes of vital phenomena. If the latter, it must be confessed that science has gained nothing by these inventions.

In the same manner, say these physiologists, as attraction presides over the changes of state in dead matter, does the vital power control the modifications of organized bodies. But they fall into an error, for vital power and attraction cannot well be compared to each other; the laws of this last are perfectly known; those of vital power entirely unknown. Physiology is, at this time, precisely in the state in which the physical sciences existed before the discoveries of Newton, and it requires a genius of the highest order to discover the laws of vital power, in the same manner as Newton made known those of attraction. The glory of this great man does not consist in having discovered attraction, as some believe, for before his time this cause was known, but in having shown that this power "acts directly in proportion to the mass, and inversely as the squares of the distances."

* See the Synoptic Table of the Fluids.

But it is not by speculations in the closet that this point can be attained. An exact knowledge of the physical sciences, numerous experiments upon living animals, both in health and disease, together with the most severe and rigorous modes of reasoning, can alone lead to this.

Before beginning the examination of the phenomena of life in man, the principal object of this work, we will make one general remark. Whatever may be the number and diversity of phenomena presented by man during life, they may be reduced at last to these two principal ones, viz., *nutrition* and *vital action.* A few words respecting each of these phenomena are indispensable to the proper understanding of those subjects which will hereafter fall under our consideration.

The life of man, and that of other organized bodies, is preserved by the habitual assimilation of a certain quantity of matter, called aliment. If they are deprived of this for a given period, it will be necessarily followed by a cessation of life. On the other hand, daily observation shows that the organs of man, and other living beings, are constantly losing a certain portion of the matter of which they are composed. A necessity, therefore, for repairing the loss which is thus constantly sustained, is the reason why the habitual use of aliments is required. From these data, and from some other circumstances which we shall mention by-and-by, it has been justly concluded that living bodies are not composed, identically, of the same matter at every period of their existence, but that they undergo a total renovation. The ancients imagined that this was accomplished in the space of seven years. But, without admitting this conjecture to its full extent, it is extremely probable that all parts of the body, during life, are undergoing a change, which has the double effect of expelling those molecules which have served their appointed time in the composition of the organs, and of replacing them by new molecules. It is this which constitutes nutrition. This process does not fall, indeed, under the cognizance of our senses; but the effects are so palpable, that it would be the height of skepticism to doubt it. In the present state of physiology, this operation cannot be attributed to chemical affinity, that power which controls the action of minute particles of matter upon each other in dead bodies, nor, indeed, do we know of any satisfactory explanation of it. To say that it depends on *organic sensibility*, or *organic insensible contractility*, or simply on *vital power*, is only to express the fact in different terms, without giving any explanation of it. But however this may be, we can only attribute to this process of nutrition the power of living bodies to preserve or change the physical properties of their organs. Our different organs being found to present different physical properties, the process of nutrition must no doubt vary in each.

Independently of the physical properties which all parts of the body present, there are a considerable number which exhibit, either continually or periodically, a phenomenon which has been

called *vital action.* The liver, for example, is endued with a peculiar power, by which it is enabled constantly to form a fluid called bile; the same remark may be applied to the kidneys in the formation of urine. The voluntary muscles, under certain circumstances, grow hard, change their form, and contract; this is another example of vital action. These vital actions are of great importance in the life of man and other animals, and particularly demand, therefore, the attention of the physiologist.

Vital action evidently depends on nutrition, and nutrition is reciprocally influenced by vital action. Thus an organ which ceases to receive nutrition soon loses its power of vital action; and organs, the action of which is frequently repeated, possess more active powers of nutrition, while in those, on the other hand, which act but little, the process of nutrition is evidently slow.

The precise mode in which vital action is performed is unknown. There takes place in the organs some insensible movement of its molecules, which can no more be explained than the process of nutrition. No vital action, however simple it may appear to be, can be considered an exception to this rule.

All the phenomena of life, therefore, may be included under these two heads, viz., *nutrition* and *vital action;* but, as the peculiar action of the particles which constitute these two phenomena cannot be perceived by our senses, this is not a point upon which we can profitably bestow much attention. We must content ourselves with investigating their results; that is, the physical properties of the organs, the sensible effects of the vital actions, and the manner in which these concur in the general processes of the living body. This is, in fact, the end of physiology, and, to attain this end, the phenomena of life have been divided into different classes, or functions.

CHAPTER II.

CHARACTERISTICS OF MAN.

[In the conformation of man there are certain peculiarities which are worthy of attention. One of the first of these circumstances is *his erect attitude* and commanding presence. In these respects he strikingly differs from and surpasses all other animals. This attitude not only imparts dignity to his appearance, but gives him great advantages in many of the conditions in which the high career to which he is destined necessarily places him. When we examine his organization, and compare it with that of the other mammalia, we perceive that in him all the details are adapted to an habitual erect posture and progression, while their conformation is such, that though some of them can assume this

position, and preserve it for a time, yet that its continuance is inconvenient and unnatural.

Man is Bimanous and Biped.

The animals which approach nearest to the human subject are monkeys, which are hence called *anthropomorphous*. But even the most perfect of them differs from him in many important particulars. In man the superior and inferior, or pectoral and abdominal, members differ essentially. The great muscular strength of his lower extremities, their expanded, wide-bearing joints, their firm attachment to the trunk, their comparatively limited motion, and greater length, compared with the superior members, all indicate that they are designed for locomotion and supporting the weight of the body, thus leaving to the upper extremities the most perfect freedom of action. On the contrary, the small size of his arms, their great extent of motion, comparatively loose articulation with the trunk, and especially the admirable conformation of the hand, with its long, delicate fingers, flexible joints, and highly-developed antagonistic thumb, indicate its entire unsuitableness to these purposes, and show that the offices to which they are destined are widely different. When we contemplate the exquisite mechanism of the human hand, and the many brilliant triumphs of art executed by this wonderful member, we are not astonished at the enthusiasm of the ancient philosophers, who attributed the great superiority of man to other animals chiefly to the possession of this surprising instrument. Thus, man possesses two hands and two feet, the offices of which are essentially different; a conformation which does not exist in other mammalia, which have either four feet or four hands.

The simiæ have four hands, the abdominal extremities being furnished with an imperfect antagonistic thumb, and capable of grasping objects precisely like the pectoral members; while the latter, as well as the former, are obviously designed for support and progression. Among the peculiarities in the structure of the lower extremities in man which impart to him the power of erect posture and progression, are his large astragalus and the great mass of muscles attached by their tendons to its posterior projecting process, constituting the calves of the legs. Other animals are destitute of these arrangements. In none of the anthropomorphous animals are these parts developed; hence, when in an erect posture, they stand on the sides of the feet, and their gait is necessarily constrained, tottering, and unsure.

The inferior extremities in man are also remarkable for their length as well as great muscular power. They are as long as the head and trunk united, which does not occur in any of the monkey tribe. This facilitates his erect attitude and locomotion, while it renders progression in a horizontal posture difficult and laborious. On the contrary, in the apes, the pectoral are generally longer than the abdominal members; in the orang-outan the hands reach to the ankles.

Vertebral Column.

The *Spinal Column* in the human subject presents also some peculiarities that deserve attention. Its outline is that of a truncated pyramid, the lumbar portion being much the largest. It is not straight, but waving in the antero-posterior direction, in which it differs from that of other animals. The manifest object of these curves is to assist in an equal distribution of the weight of the trunk, and are such that a vertical line drawn from its summit would fall in the centre of its base. The spinous processes of the lumbar vertebræ are proportionally more prominent and stronger than in other animals. This is evidently designed to favour the attachment and action of those muscles which counteract the tendency of the body forward, arising from the weight of the abdominal and thoracic organs. On the other hand, the spinous processes of the dorsal and cervical vertebræ are much smaller than in those animals whose position is naturally horizontal, as they require in the latter great prominence and strength for the attachment of the powerful tendons and muscles which support and move the head and neck.

Pelvis.

The form of the *Human Pelvis* is also highly characteristic. Its expanded ilia, shallow symphisis pubis, and incurvated sacrum terminating in the coccyx, form a shallow, basin-like cavity widely different from the elongated ilia and straight sacrum of the simiæ and other mammalia. The sacrum, which greatly exceeds in size that of other animals, presents at its upper part a firm basis for the support of the vertebral column, while its lower part, terminating in the os coccygis, projects forward so as to form a strong bony resistance at the inferior opening of the pelvis. The strong, expanded bones of the pelvis form suitable points for the attachment of the large muscular masses required to support the trunk upon the inferior extremities. To its posterior surface are attached the powerful glutæi, the largest muscles of the body. This part is rendered more prominent by large adipose deposites, which, together, form the nates. The buttocks, like the calves of the legs, have been considered by both ancient and modern physiologists among the most striking characteristics by which man is distinguished from other animals.

Thorax.

The form of the *Thorax* is likewise evidently modified by the erect posture to which man is destined. It is flattened at its anterior part, but expands laterally, and is very capacious. This arrangement spreads apart the shoulders, and is favourable to the free motion of the arms, while it diminishes the weight of the body anteriorly. It is alleged that in no other animal is the antero-posterior less than the lateral diameter of the chest. It dif-

fers widely in this respect from the narrow, keel-shaped thorax of quadrupeds.

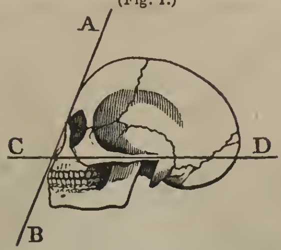
Head.

In *the Head* are lodged numerous important organs, developed in various degrees in different animals, which necessarily leads to great variety in the form of this part. It is the seat of the encephalon, the great controlling power of the body; of the organs of the senses, and is intimately connected with deglutition and respiration, the chief organs by which animals are related to external objects. From the nature of these organs, it is obvious that they must be variously developed, and that their dimensions, form, weight, and arrangement must necessarily vary in different animals, according to their destined attitude and habits.

The predominant character of man is intellectuality, while his senses are subordinate to this function more than other animals. The encephalon or cranial portion of the head is therefore developed in him in a corresponding degree. The prominent characteristics of other animals, on the other hand, are much more intimately connected with one or more of the other organs, the intellectual functions being altogether subordinate. These circumstances, with their natural attitudes, thus furnish a key to the peculiarities observed in the head of man when compared with other animals. The head is obviously divisible into those parts occupied by the organs of the senses, or *the face*, and the encephalon. One of the most remarkable circumstances observed in contrasting the head of man with other animals is his large cranium and small face. It will be found generally true in all animals, in the outline presented by a vertical section of the head in the antero-posterior direction, that, as the proportion of the cranium exceeds that of the face, the intelligence increases, and *vice versa.* This rule holds generally good, not only as regards different animals, but the various tribes of men. Camper proposed what he called the facial angle as a simple, and, generally, accurate method of expressing these proportions. Supposing the skull to be viewed in profile, and a line drawn from the greatest projection of the forehead to that of the upper maxillary bone, this may be called *the facial line.* If a second line be drawn from the meatus auditorius externus along the floor of the nasal fossæ, so as to follow the direction of the base of the cranium until it touches the first line, the angle thus formed will be the *facial angle of Camper.* It is evident that this angle will increase as the anterior portion of the cranium becomes developed and the face smaller, and the reverse as the face is more prominent and the forehead retreating. This angle is about 80° in the Caucasian race; about 70° in the negro; while in the different varieties of monkeys it varies from 60° to 30°.

The following figure represents an outline of the skull of the negro, with the lines which form the facial angle of Camper.

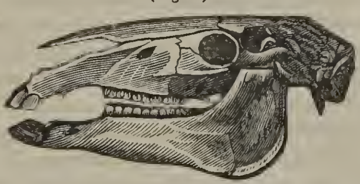
(Fig. 1.)



A B is the facial line ; C D the second line passing through the auditory passage.

As we descend in the scale of animals the facial angle becomes very acute. Thus in the horse, as will be seen in the following figure, the forehead is very retreating and the angle very acute. In some of the birds and reptiles it cannot be measured. The ancient Greek artists appear to have been aware of the majesty imparted to the human countenance by a large facial angle. Thus, to give effect to their representations of the gods and distinguished men, they exaggerated this angle much beyond what occurs in nature, carrying it to 90°, and even farther. But in their finest statues it does not exceed this. When pushed beyond this point it causes obvious deformity.

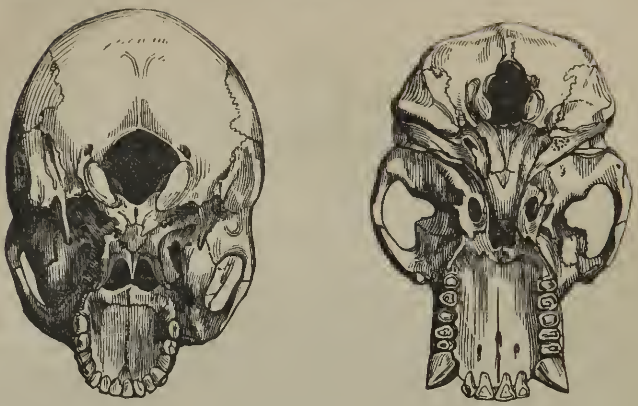
(Fig. 2.)



On examining the *base of the cranium*, we find indications similar to those above described. In man, the foramen magnum, through which the medulla spinalis passes to the spine, is placed nearly in the centre, but a little posteriorly, so as to counteract the greater weight of the posterior portion of the head. Still the head is not exactly balanced when the person is erect and all the muscles relaxed, but inclines anteriorly. But this is prevented generally by the action of the muscles attached to the occiput, by which the head is kept erect without a consciousness of effort. In quadrupeds, the natural posture being horizontal, the foramen magnum is placed near the posterior part, instead of the centre of the base of the cranium. This is strikingly shown in the following delineation of the base of the cranium in man and the orang-outan, after Mr. Owen.

In other mammalia, *e. g.*, the horse, as shown figure 2, this peculiarity is still more remarkable ; the foramen magnum is placed at the back of the skull. In this class of animals the head is attached to the spine, and kept in place by a strong ligament, the ligamentum nuchæ, which extends from it to the spinous

(Fig. 3.)



processes of the cervical and dorsal vertebræ. But, as there is scarcely a vestige of this ligament in the human subject, and from the great weight of his head, standing in a horizontal posture is necessarily unnatural and painful to him.

In man, as we have seen, especially in the Caucasian race, in which the facial angle is large, the forehead is nearly on a line with the face. But this arrangement does not exist even in the most anthropomorphous animals; on the contrary, the face projects far beyond the forehead, so that in them the anterior lobes of the brain are not placed over it, as in the human subject. This prominence of the face, or, as it is more commonly called in the inferior animals, *the muzzle*, is adapted to the horizontal posture, and is favourable to the development and action of the organs placed in this part. The nose or *snout* in many of the quadrupeds is a highly-developed organ, and occupies a considerable portion of the face; while in most animals the mouth is not merely destined to mastication, but is the chief organ of prehension and weapon of offence and defence. Hence the size and form of the nose and mouth in man differ essentially from them. The mouth in man is chiefly destined to mastication, taste, and speech; it does not, therefore, present the strong and widely-expanding jaws, powerful muscles, and formidable fangs so characteristic of many animals. Even the mouth of the orang-outan, with its elongated jaws, its short, strong incisors, and formidable cuspidati teeth, is very different from the small, arched mouth of man. It is also quite evident that this development of the muzzle in quadrupeds is in keeping with their horizontal posture.

Finally, when we compare the outline presented by man with that of the orang-outan, the most manlike of the simiæ, we are particularly struck with the length and power of his lower extremities, the breadth and solidity of the feet, with the strong projecting os calcis, and the vast muscular masses by which they are moved, especially the powerful glutæi and gastrocnemii muscles.

These, together with the short arms, broad pelvis and chest, the graceful position of the head upon the vertebral column, the small face, the noble, expanded forehead and capacious cranium, impart an imposing majesty to his appearance, which forms a remarkable contrast to the most perfect of those animals which most nearly resemble him.*

Intellect.

But though man surpasses other animals in the grace and dignity of his person, yet in many respects he is inferior to them in his physical constitution. In muscular strength, offensive and defensive weapons, the certainty of his instincts, the acuteness of his senses, in provisions against the inclemency of the weather, and the protracted helplessness of his childhood, his inferiority is obvious. How, then, has he acquired those great advantages which place him, out of all comparison, at the head of the animal kingdom? This is chiefly attributable to a peculiarity which constitutes by far his highest distinction. We refer to his intellectual endowments, the *mens divinior;* all his other gifts are chiefly available as they are the ministers of his intellect.

One of the most obvious and effectual means of acquiring his superiority over other animals is combining his efforts with others of his species. Man is naturally and necessarily social. The life of a solitary individual, notwithstanding all that fiction has imagined, must be unavoidably precarious and miserable. He is prompted not only by his instinctive tastes, but by a perception of his individual weakness and collective strength, to seek the society of his fellow-man.

To counteract his deficiency in mere physical strength and natural weapons, he taxes his ingenuity and industry, and procures those which are artificial, and which are in some respects superior to the natural arms of other animals, which are always few in number, incapable of improvement, and their usefulness necessarily limited to the individual. But man can imitate most of these contrivances and multiply them at his pleasure, and thus unite in himself all the varied endowments of other animals. They are not only available to himself individually, but may be imparted to those associated with him, and transmitted to those who come after him. An immense range of objects is thus brought under his control. Every department of nature is made subservient to his purposes. The qualities of the fleetest and strongest animals are appropriated to his use, as if they were his own; the fiercest are dragged from their burning deserts as trophies of his power; the depths of the seas are made to render up their gigantic inhabitants for his convenience and luxury; while the earth, vexed by his labour and skill, is compelled to yield her choicest treasures, her loveliest forms, and most fragrant perfumes, for the gratification of his senses.

He is thus enabled to provide not only for his first and most

* See the Frontispiece, outline of Man and the Orang-outan.

urgent wants, but to attend to those circumstances which improve his intellectual powers, invigorate his health, prolong his life, and embellish his existence.

But though the strong distinctive character of man is his intellect, yet this power is by no means exclusively confined to him. Among the inferior animals we find their instinctive perceptions stronger, their affections and passions more ardent, their memory tenacious, and undoubted evidences of thought, reasoning, and imagination. The difference of intellect, then, is rather in degree than kind, though that difference is vast.

But he possesses a few faculties of which other animals are destitute. One of the most striking of these, and which is intimately connected with his intellect, is the vast power and flexibility of his voice, and his capacity of inventing and uttering articulate words, by which he is enabled to communicate the slightest differences or shades of thought. This is a most copious and unfailing source of social enjoyment and happiness, as well as of moral and intellectual development. Another of these peculiarities is his capacity for improvement. Other animals rapidly attain their highest degree of development, and then remain stationary. If any individual happen to possess any superiority, he is incapable of imparting it to others; thus all successive generations remain in nearly the same state. How different in this respect is man! The degraded Hottentot, or native of New South Wales, scarcely equals the inferior animals in the moral dignity of their character. But how striking the contrast which civilized man presents! No one can predict the elevation to which the human character is ultimately destined. But when we look back at what has been actually accomplished, even within a short time, we are dazzled by the possibility of the future. But perhaps the most remarkable of these characteristics, and the last to which we shall allude, is his consciousness of, and sense of, accountability to an overruling and resistless power, which is neither seen, nor heard, nor appreciable by any other of his senses. Some have alleged that the existence of a God is an obvious and unavoidable deduction of reason; that the admirable order and adaptation of everything we see necessarily implies design, and this design a designer. But though it be admitted that the wonders of nature that everywhere surround us proclaim to the enlightened mind the present God; though reason undoubtedly comes in with its high sanctions to confirm and regulate the suggestions of this religious or moral sense, yet it would seem that this is an original endowment, written in our very constitution, and to a certain extent independent of, and superior to, reason. Other animals, as we have seen, possess reasoning powers, but man is the only inhabitant of this planet that gives any evidence of his consciousness of the existence of such a power, and of certain moral duties and obligations as a means of conciliating this being. It is this alone that enables him to paint the dark and mysterious future with a thousand brilliant, flattering hopes, and "to place, as

it were, a crown of glory on the cold brows of death." This faculty shows itself under a great variety of forms, and is mingled in many instances with grossness and absurdity. It exists in different degrees of power in different individuals. Like the other faculties, it is developed and strengthened by cultivation and exercise, and by neglect shrinks away and almost disappears, or it may be exalted to disease. But its universality, its exact adaptation to our wants and situation, its influence on our present happiness, and the exalted motives of action that it holds out, all conspire to render this the noblest attribute of our species.—*Ed.*]

CHAPTER III.

CLASSIFICATION OF THE FUNCTIONS.

Authors have differed much in their division of the functions. Without stopping to enumerate the different classifications that have been adopted at different epochs of science, which does not comport with the nature of this work, we shall divide the functions, 1st, into those which connect the individual with surrounding objects; 2d, those of nutrition; 3d, those which have for their aim the reproduction of the species. We may call the first *functions of relation;* the second, *functions of nutrition;* and the third, *functions of generation.*

The method to be pursued in the investigation of a function is by no means a matter of indifference. The following is the one which we have adopted:

1. General idea of function.
2. Circumstances which keep up the action of organs, and which we call *excitants of functions.*
3. Concise anatomical description of the organs concurring in any function, and which may be called its *apparatus.*
4. The action of each organ in particular.
5. A summary showing the utility of the function.
6. The relation of the function to the parts before examined.
7. The modifications which the function exhibits, according to age, sex, temperament, climate, season, and habit.

THE FUNCTIONS OF RELATION.

VISION.

The functions of relation include *Sensation, Intelligence, Voice,* and *Motion.*

Sensations are those functions which are destined to receive impressions from external objects, and to convey them to the sensorium. These functions are five in number, viz., *Seeing, Hearing, Smelling, Tasting,* and *Feeling.*

Vision is the function by which we become acquainted with the size, figure, colour, and distance of bodies, &c. The organs which compose the *apparatus of vision* act under the influence of a particular excitant, called *light.* We perceive bodies, and become acquainted with many of their qualities, although they may be at a considerable distance from us; there must, therefore, be some intermediate agent between these objects and our eyes; this agent is *light.* Light is supposed to be an exceedingly subtile fluid, which emanates from a class of bodies called luminous; as, for example, the sun, fixed stars, ignited substances, and those that are called phosphorescent, and is composed of particles which move with a prodigious velocity.

[But we know nothing of the intrinsic nature of light; we can only conceive of it and study its properties. This would be the logical course, but we are not satisfied with this; we require a supposition upon which the mind can repose itself, and, as it were, go to sleep. It was supposed by Newton that light emanates, in the form of molecules, from luminous bodies. Des Cartes proposed another hypothesis. He supposed that space was filled with a very subtle fluid, *the ether*, and that luminous bodies caused vibrations or undulations in this ether, which was light.

Of these two modes of conceiving and explaining the phenomena of light, the Newtonian, or *system of emission*, as it is usually called, is the most simple and easy of comprehension, and explains adequately all the more common phenomena, though in some particulars defective, and is the one which we shall use. The second, or *system of undulations*, explains with great precision the most minute of these phenomena, and affords great facility to mathematical calculations. But for a complete comprehension of this system, extensive mathematical knowledge and familiarity with abstract science is indispensable.

All the phenomena which light presents constitute the science of *optics.* It is divided into two parts: the first, which is called *Catoptrics*, relates to the phenomena connected with the reflection of light. The second, known by the name of *dioptrics*, is concerned in the phenomena presented by light when it passes through bodies.

It was long supposed that light passed instantaneously from one point to another. Rœmer first demonstrated that light required a certain time in passing through space, by showing that it was not instantly transmitted from the satellites of Jupiter. By carefully observing their eclipses, he proved that they remained visible for some time after they should have disappeared behind that planet, and that they did not appear at the opposite side until some moments after the time that they must have been disengaged from its disc. A great number of accurate observations have demonstrated that light moves at the rate of eighty thousand leagues in a second, and requires about 8′ 13″ to reach us in passing from the sun. Hence, from the immense spaces by which the heavenly bodies are separated from each other, they are nev-

er actually seen at the points at which they appear to us. It has been computed that light probably requires many years to pass to us from the smallest of the fixed stars. It is ascertained that it requires about three years from the nearest of the fixed stars.

The velocity of light, assuming that it consists of molecules, may give some idea of the size of these molecules. The *momentum of a body* consists of its mass and velocity combined. The *momentum* of light is just sufficient to affect the retina, the most delicate and sensible structure of the body. Now if we suppose a molecule of light to be one of the smallest masses that can be calculated, its momentum would exceed that of a musket-ball. What, then, must be the mass, seeing they do not injure the retina!

As light moves in right lines, and cannot traverse certain bodies which are called *opaque*, it necessarily happens that, when such bodies are exposed to a ray of light, that there is a space behind which is deprived of light; this is the *shadow*.*]

A *ray of light* is a series of particles succeeding each other, without interruption, in a right line. The particles which compose a ray are separated from each other by considerable intervals, relatively to their masses. This may be shown by making a large number of rays cross each other at any given point, when it will be perceived that the particles do not strike against each other in meeting.

Light, in passing from luminous bodies, forms diverging cones, which, if they meet with no obstacles, are prolonged indefinitely. Natural philosophers have inferred from this, that the intensity of light received from a luminous body in any given spot is in an inverse ratio to the squares of the distances of the surface of the luminous body from which it arises. Those bodies which transmit the light are called *media*. When light meets in its progress certain bodies called opaque, it is turned from a right line, and the direction given to it is modified by the disposition of the surfaces of those bodies. The change of direction which the light undergoes in this case is called *reflection*.

Certain bodies transmit light, or suffer it to pass through them; for example, glass. These are said to be *transparent* or *diaphonous*. In passing through them, the light undergoes a certain change, called *refraction*. As the mechanism of the organ of vision, from its structure, depends entirely upon the principles of refraction, it will be necessary to stop for a moment, for the purpose of examining the subject.

The point at which a ray of light enters a medium is called the *point of immersion*, and that from which it passes out, the *point of emergence*. If a ray enters perpendicularly the surface of a medium, it passes through the medium preserving its first direction; but if it strikes obliquely to the surface of the medium, it is turned from its course, so that it appears broken at the point of immersion.

The angle of incidence is that contained between the incident

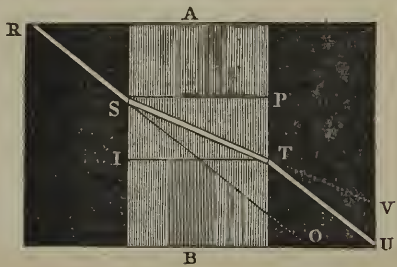
* Physique Medicale.—*Magendie.*

ray and a line drawn perpendicularly to the surface of the medium from the point of immersion. The angle of refraction is that contained between the line described by the refracted ray and a line perpendicular to the refracting surface at the point of immersion.

A ray of light passing from a rarer into a denser medium is refracted towards a perpendicular to the surface of the denser, drawn from the point at which the ray meets the medium; but, on the contrary, in passing from a denser into a rarer, it is refracted from the perpendicular. When a ray of light passes from a rarer through a denser medium, the two surfaces of which are parallel, the ray, in passing into the surrounding air, will take a direction parallel to that of the incident ray.

[This may be illustrated by the following diagram.

(Fig. 4.)



Let A B represent a dense medium, as a piece of glass, with air on either side. R, a ray of light striking the surface of glass obliquely at S, the point of immersion. Instead of pursuing its original course along the line R S O, it will be refracted or turned in the direction S T, towards the line S P, which is perpendicular to the surface of A B, the denser medium. When the ray arrives at T, passing from the denser into a rarer medium, it will be again refracted or turned, but in an opposite direction, and describe the course T U instead of T V.

But if the course of the ray be perpendicular to the surface of the denser, it passes through without undergoing any change in its direction.—*Ed.*]

Bodies refract light in proportion to their density* and combustibility. Thus, if two bodies be of equal density, but one more combustible than the other, the refractive power of the first will be found greater than that of the second. All diaphonous bodies, at the same time that they refract light, reflect it. In proportion as bodies possess this last quality, they are capable of being used as mirrors. When they have but little density, as, for example, the atmospheric air, they are only visible when they exist in considerable volumes.

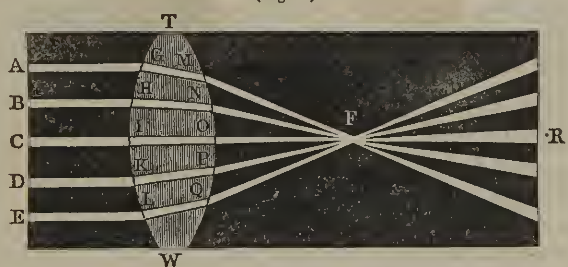
The form of refracting bodies has no influence upon their re-

* Density is the relation of weight to volume. If all bodies were of the same volume, their relative density might be determined by their weight.

fracting power, but it modifies the disposition of the refracted rays with respect to each other. The perpendiculars at the surface of the refracting body approaching or separating from each other, according to the form of the body, the refracted rays must also converge or diverge from each other. When, from the form of a refracting body, the rays are made to converge, the point where they unite is called *the focus of the refracting body.* Bodies of a lenticular form, or those bodies which are terminated by two segments of spheres, present this phenomenon. A refracting body with parallel surfaces does not change the direction of the rays, but approximates them towards its axis by a sort of transport. A refracting body with two convex surfaces, called a lens, does not possess a greater refracting power than a body which is convex on one side and plane on the other, but the point where the rays unite is nearer.

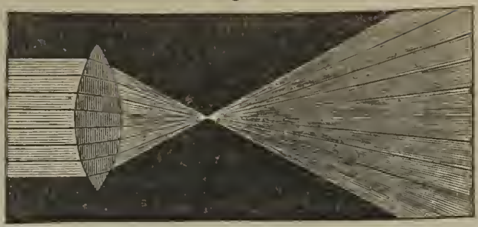
[Refracting media, terminated by curved surfaces, produce different effects upon light, according to the nature and arrangement of the curved surface. In order to collect a pencil of rays proceeding from a distant object accurately to a focus, the dense medium must be of a lenticular form. If we suppose the object to be very remote, the rays composing the pencil must be nearly parallel, as in the following diagram.

(Fig. 5.)



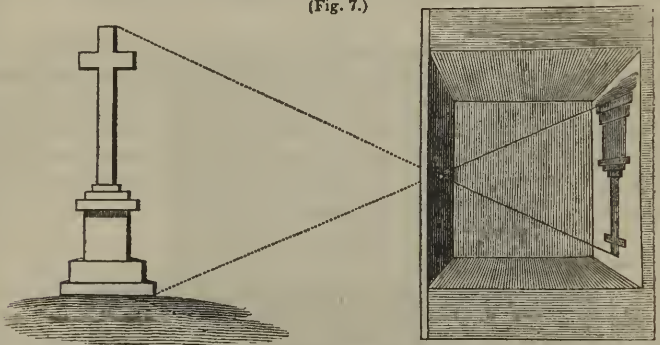
Let A B C D represent the rays, and T W the lens. There will be one of these rays, and but one, viz., C I, which strikes the lens perpendicularly, and will, therefore, continue its rectilinear course to R without undergoing any refraction. B and D, situated near the central ray, will undergo a small degree of refraction, the obliquity in the surface of the lens being but slight at this point. But the rays A and E, striking the lens at a point where there is greater obliquity of the surface, will undergo a greater amount of refraction, which is required in order to bring them to the same focus. M N O P Q represent the convex surface of the posterior part of the lens, through which the rays emerge when passing into a rarer medium. According to the same law, this increases the convergence of the rays. Thus, by making the denser medium convex on both sides, both surfaces concur in producing the desired effect. This is called *a double convex lens*, and is more strikingly shown in the following diagram.

(Fig. 6.)



When the rays of light are transmitted through the same medium, they proceed in straight lines. Let us imagine a dark chamber into which no light is allowed to enter except by a single small aperture, as is shown in the following diagram.

(Fig. 7.)



It is evident that each ray will, in that case, illumine a different part of the wall. Thus, the whole external scene will be faithfully represented, though it will be in an inverted position. This inversion of the image is a necessary consequence of the crossing of all the rays at the small aperture through which they are admitted. It must also be a necessary result of limiting the illumination to a single ray, that the image thus formed will be very faint. If the aperture were enlarged, the image, indeed, would be brighter, but more indistinct from the intermixture and mutual interference of adjacent rays. The only mode by which distinctness of the image can be obtained is to increase the number of rays. This may be done by means of a double convex lens.

If, then, in a dark chamber (as in fig. 7), we enlarge the aperture and fit into it a double convex lens, we form a camera obscura. In this well-known optical instrument, the images of external objects are formed upon a white surface of paper, or a semi-transparent plate of glass. These images must evidently be in an inverted position with respect to the actual objects that they represent. There is a striking analogy between the construction of the camera obscura and the eye. The latter, however, is greatly superior in many respects, particularly in its spherical shape, by which the retina is enabled to receive every portion of the images produced by refraction, which are themselves curved.

Whereas, if received on a plane surface, as in the camera, a considerable portion of the image would be indistinct.—*Ed.*]

The study of refraction makes us acquainted with an extremely important fact: it teaches us that a beam of light is composed of an infinite number of differently-coloured rays, which are differently refrangible; *i. e.*, if the medium and angle of incidence be the same, the refraction of the rays differ with their colour. If, in a room previously darkened, we allow a beam of light to pass through a small aperture, so that it will traverse a prism of glass, or any other refracting body, the surfaces of which are not parallel, and if this be received on any plain surface, as, for example, a sheet of paper, it will be seen that the beam occupies a considerably larger space than the size of the aperture, of an oblong form; and, instead of producing a white image, a number of different colours will be observed, which run insensibly into each other, and among these may be distinguished the seven following colours, viz., red, orange, yellow, green, blue, indigo, and violet. Neither of these colours are capable of being decomposed; they are together called the *solar spectrum.* Light is not, therefore, homogeneous, but is composed of very differently-coloured rays. On this fact is founded the explanation of the different colours of bodies. A white body reflects light without decomposing it; a black body does not reflect light, but totally absorbs it; coloured bodies decompose light, and reflect it; they absorb some of the rays and reflect others. Thus a body will appear red when the red rays are alone reflected and the rest absorbed, or will appear green when the union of the colours reflected form green. Transparent bodies also appear coloured from the light which they refract, and when seen by refraction, they appear of a colour different from what they seemed by reflection. If, now, it be inquired why certain bodies reflect one ray and absorb another, it will be replied, that this phenomenon arises from the peculiar arrangement of the particles of which the body is composed.

[The seven colours of the prism are evidently, then, the constituent parts of the white light; if they are all made to converge upon the same surface by means of seven mirrors, the white light is reproduced. Again, if we unite on one side three of the rays, and on the other side the other four, we obtain two shades which are obviously complements of each other, and which produce white light when united.

Newton supposed that the power of refracting media to separate the coloured rays from each other was in proportion to their refractive force. But Dollond discovered that the two properties were not necessarily connected, and that a body might refract less than another and disperse more. This enabled him to preserve in a prism, or a compound glass, the power of refraction and destroying that of dispersion of light. This fortunate result is known by the name of *achromatism,* or privation of colour, because, by the aid of certain combinations, we can prepare lenses which give white images, or, at least, preserve the natural colour

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of objects. The two substances which compose *achromatic glasses* are common glass, without lead, commonly known as *flint-glass*, or glass containing a large quantity of the oxide of lead, called *crown-glass*.*]

The discovery of the action of refracting bodies upon light has not been a mere object of curiosity, but has led to the construction of ingenious instruments, by means of which the sphere of human vision has been astonishingly extended.

Apparatus of Vision.

The *apparatus of vision* is composed of three distinct parts. The first modifies the light, the second receives the impression of this fluid, and the third transmits this impression to the sensorium. The structure of this organ is extremely delicate. Nature has taken, therefore, great care to place before it various parts, which protect and preserve it in a condition necessary to the free and easy exercise of its functions.

The protecting parts are the eyebrows, the eyelids, and the apparatus for the secretion and excretion of the tears.

The eyebrows are peculiar to man, and are formed,

1. By hairs of various colours.
2. By skin.
3. By sebaceous follicles placed at the root of each hair.
4. By muscles destined to move it, viz., the frontal portion of the *occipito-frontalis*, the superior edge of the *orbicularis palpebrarum*, and the *corrugator supercilii.*
5. By numerous bloodvessels.
6. By nerves.

The eyebrows have various uses. The projections which they form protect the eyes from external violence. The hairs, from their oblique direction, and from the oily substance with which they are covered, prevent the sweat from running into the eye, and irritating the surface of the organ ; they direct it towards the temple and root of the nose. The colour and number of the hairs of the eyebrows have some influence upon their use. These are found to have some relation to the climate. The inhabitants of warm climates generally have them very thick and very black. The inhabitants of cold regions may have them thick, but they are seldom black. The eyebrows guard the eye from the too vivid impression of light, particularly when they are drawn together, as in the act of frowning.

The eyelids are two in number in man, and are divided into superior and inferior, or great and small—*palpebra major* and *palpebra minor.* The form of the eyelids is accommodated to that of the globe of the eye, so that, when they are brought together, they completely cover the anterior surface of that organ. They do not meet on a level with the transverse diameter of the eye, but considerably below it; this was, therefore, falsely called by Haller *æquator oculi.* The more extended the opening that

* Physique Medicale.

separates the eyelids, the larger the eye appears; the opinion we form of the size of the eye is often, therefore, very incorrect. The open edge of the eyelids is thick, firm, and furnished with hairs, more or less numerous, which are, generally, of the same colour with the hair of the head. These hairs are placed very near to each other. Those of the superior eyelid form a slight curve upward, but those of the inferior eyelid turn in an opposite direction. When they are very numerous and very long, they are considered beautiful; an idea which agrees very well with the utility resulting from them. The eyelashes are covered with an unctuous substance, derived from the small follicles situated in the thickest part of the eyelids, near the roots of the eyelashes. They have these, in common with the hair, in most parts of the body. Between the line occupied by the eyelashes and the internal surface there is a smooth edge, where the eyelids touch each other. This may be called the *margin of the eyelids.*

The eyelids are composed of a muscle with semicircular fibres, the *orbicularis palpebrarum*, of a cartilage, of a ligament, the *large ligament of the eyelid*, of a great number of sebaceous follicles, *meibomian glands*, and a portion of mucous membrane. All these parts are connected together by cellular membrane, generally loose and fine, and containing no fat. The skin of the eyelids is very fine and semi-transparent; it adapts itself readily to their movements, and presents transverse folds. The muscle of the eyelids, by its contraction, approximates them, or, as we commonly express it, shuts the eye, at the same time that it presses the eyelids a little upon the globe of the eye.

The cartilages of the eye are called *tarsi*. That of the superior is much larger than the inferior; their use is to keep the eyelids extended, and constantly accommodated to the form of the eye; they also support the eyelashes, afford a suitable situation for the meibomian glands, and serve to protect the eye from external injury. The use of the tarsi, as respects the motion of the eyelids, does not appear indispensable, as they are not found in many animals, the eyelids of which, nevertheless, perform their functions well. The large ligament is nothing more than the cellular membrane which passes from the base of the orbit to the superior edge of the cartilage of the tarsus. It seems intended to limit the motion by which the eyelids approach each other.

The cellular tissue of the eyelids is extremely fine and delicate, and contains no fat, but is filled with a very thin serum, which in some cases has a greater degree of consistence, and accumulates in the cells of this tissue; when this is the case, the eyelids become distended, and of a bluish colour. This colour and swelling of the eyelids is frequently observed after excesses of every kind, after severe diseases, during convalescence, and in women during menstruation, &c. The fineness and laxity of the cellular membrane of the eyelids, and the absence of fat from its cells, are necessary for their free motion. The internal surface of the eyelid is covered by a mucous membrane. Besides the parts already

mentioned, the superior eyelid has a muscle proper to it: this is called the elevator palpebræ superioris.

The eyelids cover the eye during sleep, and preserve it from the contact of foreign bodies which float about in the atmosphere; they preserve it from blows by their instantaneously closing; by habitually closing at nearly regular intervals, they prevent any bad effect from the long-continued contact of the air, and have likewise the power of moderating the effect of a too brilliant light. By closing together, they only suffer such a quantity of light to pass as may be necessary for vision, but not sufficient to injure the eye. On the other hand, when the light is weak, we separate the eyelids widely, so as to permit the largest quantity of light possible to penetrate to the interior of the eye. When the eyelids are near, the eyelashes form a sort of grate, which only suffers a certain quantity of light to pass at a time. When the eyelashes are moist, the small drops which cover their surfaces decompose the light in the manner of a prism, and, at the point where the light passes, cause it to appear variegated like the rainbow. The eyelashes, by dividing the light which penetrates into the eye into pencils, cause ignited bodies to appear, during the night, as if they were surrounded by luminous rays. These appearances vanish as soon as the eyelid is thrown back, or another direction given to the eyelashes. It is supposed that the eyelashes preserve the eye from the atoms of dust which are floating in the air. Vision is always more or less affected in those persons who have lost the eyelashes.

The compound follicles placed in the thickest part of the tarsi are called the meibomian glands. They are very numerous. There are from thirty to thirty-six in the upper eyelids, and from twenty-four to thirty in the lower. In each compound follicle there exists a central duct, about which are placed the simple follicles, and into which they pour the matter they secrete. This duct is always filled with the matter, which, in its ordinary state, is called the meibomian humour, but when it is thick and dry, is called *gum*. After sleep, a certain quantity of this is always found accumulated in the inner angle of the eye and on the margin of the eyelids. This matter seems to be of an unctuous nature, but particular researches have induced me to believe that it is essentially albuminous. Each central duct has an opening, hardly visible, on the internal surface of the eyelid, very near to the margin.

These openings are close to each other, and range along the whole length of the margin. The meibomian humour passes out through these openings when we compress the eyelids tightly; as they experience a sensible pressure on closing the eyelid, it is probable that this pressure contributes to the excretion of the humour. The principal use of this humour seems to be to diminish the friction of the eyelids on the globe of the eye. As the upper eyelid has a greater extent of motion, and will, of course, produce more friction, it requires a greater number of these follicles.

Apparatus for the Tears.

The office of guarding the eye, and preserving it in a condition necessary for the performance of its functions, is not confined exclusively to the eyebrows or eyelids. There is likewise to be reckoned among the *tutamina oculi* a small secretory apparatus, of which the mechanism is very curious, and the utility very great. This is the secretory apparatus of the tears. It is composed of the lachrymal gland, the excretory ducts, the caruncula lachrymalis, the lachrymal ducts, and the nasal duct.

In the small fossa, formed at the anterior and outer part of the arch of the orbit, is placed the lachrymal gland; it is small, and serves to secrete the tears. This gland was known to the ancients, and was called by them the *glandula superior innominata*, in opposition to the *caruncula lachrymalis*, which they called the *glandula innominata inferior*. They attributed the formation of tears partly to the caruncula, and partly to a gland that does not exist in man, but is found in certain animals: this is the *gland of Harderus*.

There are six or seven excretory ducts of the lachrymal glands. They arise from the small glandular bodies that together form this gland. After having passed through the substance of the gland, they enter the conjunctiva, and pierce this membrane very near the cartilage of the upper eyelid, towards its external extremity. They may be rendered visible by blowing into them, or by raising the upper eyelid, and compressing the gland, when the tears will be made to pass out of the orifices of the ducts. This may likewise be done by macerating them in water tinged with blood, or by injecting them with mercury. The tears are poured through these orifices upon the surface of the conjunctiva.

At the internal angle of the eye is seen a small, projecting, red body, which, when it is of a bright colour, indicates health and vigour; when it is pale, debility and disease: this is the *caruncula lachrymalis*. This small body is composed of seven or eight follicles, ranged in a semicircular line, the convexity within; they have each an opening on the surface of the caruncula lachrymalis, and contain a small hair. These openings are so disposed that they complete, together with the meibomian glands, a circle embracing the whole anterior part of the eye when the lids are closed.

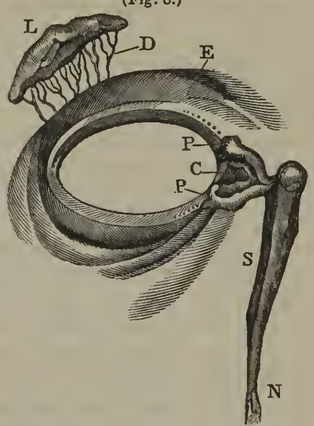
At the point where the eyelids leave the globe of the eye to include the caruncula, on the internal surface, near the open edge, on each lid, is seen a small opening: these are the *puncta lachrymalia*, or external orifices of the lachrymal ducts. The *puncta* are always open, with their orifices directed towards the eye. It has been supposed that they possess a contractile power, which may be shown by touching their extremity with a pointed instrument. Though I have often endeavoured, with great care, to distinguish these contractions, yet I have never succeeded. One circumstance should be mentioned which is extremely apt to deceive us. When we unsuccessfully attempt to introduce the *style*,

the mucous membrane, which covers the puncta, becomes soon irritated and swelled, as would occur from the same violence at any other part, when the opening will, of course, be diminished. It is necessary to distinguish this phenomenon from a contraction of the part.

The lachrymal ducts arise from the puncta, and terminate in a canal extending from the inner canthus of the eye to the nasal fossæ. The lachrymal ducts are very narrow, scarcely suffering a hog's bristle to pass. They are from three to four lines in length, and are placed in the thickest part of the eyelid, between the orbicularis muscle and the conjunctiva. They terminate sometimes singly, and sometimes together, in the superior part of the nasal canal.

The canal extending from the inner angle of the eye to the inferior passage of the nasal fossæ has been improperly divided by anatomists in two parts. This canal is throughout of the same dimensions ; there is nothing, therefore, to justify the distinction that has been made, in calling the upper part the *lachrymal sac*, and the lower the *nasal duct.* This canal is always formed by the mucous membrane of the nasal fossæ, which covers the osseus duct, passes along the posterior edge of the projecting apophysis of the maxillary bone, and the anterior part of the *os unguis.* Its use is to conduct the tears into the nasal fossæ.

(Fig. 8.)



[L is the lachrymal gland, situated above the eye, in a hollow of the orbit. D the ducts proceeding from it, and opening upon the inner side of the upper eyelid at E. The eyelids, in closing, meet first at the outer angle, the junction proceeding towards the inner angle, until the contact is complete. By this means the tears are carried in that direction, and accumulated at the inner angle. They are conveyed off by two ducts, the orifices of which, P P, are the *puncta lachrymalia.* C is the lachrymal caruncle. The two ducts unite, and open into the lachrymal sac S, situated at the upper part of the side of the nose, and which terminates below at N, in the cavity of the nostrils.]

The membrana conjunctiva may be ranked among those organs which constitute the apparatus for the tears. This is a mucous membrane, which covers the posterior surface of the eyelids, and is reflected over the anterior surface of the globe of the eye. It is more extensive than the part it covers, and is therefore very favourable to the motion of the eyelids and the eye. The loose manner in which it is attached to the eyelids and the *tunica sclerotica* greatly facilitates their movements. Whether the conjunctiva passes over the transparent cornea or stops at the circumference of this portion of the eye, and is then connected with a distinct membrane which covers it, is not yet perfectly decided. The general opinion is, that it covers the cornea; but M. Ribes, a very distinguished and expert anatomist, contends that the cornea is covered by a peculiar membrane, united to the conjunctiva at its circumference, without being a continuation of it. The conjunctiva protects the anterior parts of the eye; it secretes a fluid which mixes with the tears, and appears to have the same use; it likewise possesses the power of absorbing,* and, as it is very smooth and moist, it greatly facilitates the motions of the eye; lastly, it is the part in contact with the air when it is not covered by the tears, of which we are now about to speak.†

Secretion of the Tears, and their Uses.

This is not the place where we intend to enter into a minute description of the secretion of the tears, and in what it resembles or differs from other secretions. It is sufficient here to remark, that the lachrymal gland forms them through the influence of the fifth pair of nerves,‡ and that they are poured out through its excretory ducts, of which we have spoken, upon the conjunctiva, at the outer and superior part of the eye. We shall next inquire how they proceed when they have arrived at this part. They are poured out, we would observe in the first place, as well during sleep as when we are awake. In this last state, the eyelids opening and shutting alternately, the conjunctiva is exposed to the contact of the air, and the eye moves continually, neither of which happens during sleep.

Physiologists have supposed that the tears run along a triangular canal, formed to conduct them towards the inner canthus of the eye, where they are absorbed by the puncta. This canal, say they, is formed, first, by the edge of the eyelids, the surfaces

* We may poison an animal by applying to the conjunctiva poisonous substances. For this reason we cannot agree with Mr. Adams, the celebrated London oculist, who thinks that the belladonna may be continually applied to the eye without inconvenience.

† I have noticed a remarkable fact in these experiments.—(See *Journ. de Phys.*, t. iv., 1824.) The section of the opthalmic nerve is constantly followed in animals by a violent inflammation, with abundant suppuration of the conjunctiva, and subsequently, ulceration of the cornea, and discharge of the humour; but the surface of the eye remains completely insensible. Those authors who venture to explain morbid phenomena should combine such facts with their doctrines; violent inflammation, with complete loss of sensibility.

‡ I have repeatedly touched the lachrymal nerve with the point of a fine needle, to which I have afterward applied galvanism, and have uniformly observed that the moment the nerve was touched by the point of the needle, the tears flowed as abundantly as if some irritating substance was introduced under the eyelids in contact with the conjunctiva, or perhaps even more so.

of which being convex, only touch at one point; and, second, by the anterior face of the eye, which completes the triangular cavity. This canal has its external extremity more elevated than its internal. This arrangement, joined with the action of the orbicularis muscle, the most fixed point of which is attached to the projecting apophysis of the os maxillare, directs the tears towards the puncta lachrymalia.

But this explanation is defective; the eyelids have not a convex edge at the part where they come in contact with each other, but have plain margins; no such canal, therefore, can exist. Indeed, when we examine the eyelids at their posterior surface, when they are shut, it is scarcely possible to distinguish the line where they come in contact. But even admitting the existence of such a canal, it could serve as a duct for the tears only during sleep, and it would still remain necessary to show how they are disposed of when we are awake. During sleep, and at all times when the eyelids are closed, the tears spread, by degrees, over the whole surface, both of the *ocular* and *palpebral* conjunctiva. They will, of course, pass in the largest quantities to those points where they meet with the least resistance. The direction where the resistance is least is the part where the conjunctiva passes from the eye to the eyelids. In this direction they arrive more easily at the puncta lachrymalia. The tears which are spread over the conjunctiva must become mixed with the secreted fluids of this membrane, and be absorbed together.

But when we are awake, they do not pass off in this way. That portion of the conjunctiva which is in contact with the air allows the tears which cover it to evaporate, and it would become dry if the moisture were not renewed by the action of winking. This seems to be the principal use of winking. The tears, which thus constantly cover that part of the conjunctiva exposed to the air, give to the eye its polish and brilliancy.

The increase or diminution of the tears influences very much the expression of the eyes. During the excitement of the passions this is very apparent. In the ordinary state of the secretion of the tears, they do not tend, in any way, to run over the inferior eyelid. I know not how the idea has arisen that the meibomian humour is intended to prevent this, except from the supposed analogy of oily substances, which, when placed on the edge of a vessel, prevent aqueous fluids from running over, even when they rise somewhat above its level. But I doubt if this humour can have such an effect, as it is soluble in the tears.

The tears, which do not evaporate, or are not absorbed by the conjunctiva, are received into the puncta, and conveyed through the nasal duct to the nose. What the power is by which this is effected is not certainly known. It has been explained on the principle of a syphon, capillary attraction, vital properties, &c. That of capillary attraction is, perhaps, the most probable. The absorption of the tears by the puncta is not very apparent, except when they are very abundant.

Globe of the Eye.

The apparatus of vision is composed of the eye and optic nerve. The situation of the eye, at the highest part of the body; the capacity in man of discerning, at the same time, with both eyes the same object; the oblique direction of the base of the orbit; the protection afforded to the eye by this cavity from external injury; the great abundance of adipose substance and cellular membrane, which form an elastic cushion at the bottom of the orbit, &c., are curious and interesting circumstances, which should not be neglected, but which we can only mention in passing.

The eye is composed of many different parts, which perform very different offices in the function of vision. They may be divided into the refracting and non-refracting parts of the eye.

The refracting parts are, the *transparent cornea*, which is convex on one side and concave on the other. In its form, transparency, and mode of insertion, it greatly resembles the crystal of a watch.

The *aqueous humour*, which fills the chambers of the eye, is not a pure watery fluid, as its name implies, but is chiefly composed of water, with a little albumen.*

The *crystalline humour* has been compared to a lens. The comparison is correct as far as the form is concerned, but is very defective as respects its structure. The crystalline humour is composed of concentric laminæ, which increase in density as you approach the centre, but differ in refrangibility; and it is enveloped in a membrane, which we know, from experience, to be extremely important. On the other hand, we know that a lens is homogeneous throughout, and that its density and refrangibility in all its parts are the same. It has been always remarked that the convexity of the anterior surface of the crystalline humour differs considerably from its posterior surface. The last is a part of a sphere, the diameter of which is much less than that to which the anterior surface would belong. It has been generally believed that this humour was composed chiefly of albumen; but, from an analysis lately made by M. Berzelius, it appears that it contains none. It is formed almost entirely of water, and a particular substance, which has a greater analogy, in its chemical properties, with the colouring matter of the blood than with anything else.

Behind the crystalline is found the *vitreous humour*, which is so called from its supposed resemblance to melted glass.†

Each of the parts which we have pointed out are enveloped in an extremely delicate, transparent membrane. Thus, before the cornea is the conjunctiva, behind it the membrane of the aqueous humour, which covers all the anterior chamber of the eye, *i. e.*,

* According to M. Berzelius, it is composed of water, 98.10; a little albumen; muriates and lactates, 1.15; soda, with a substance only soluble in water, 0.75.

† According to M. Berzelius, it contains water, 98.40; albumen, 0.16; muriates and lactates, 1.42; soda, with animal matter soluble in water only, 0.02; total, 100.0.

the anterior surface of the iris, and the posterior face of the cornea. The crystalline is enveloped in its capsule, which adheres, at its circumference, to the membrane which encloses the vitreous humour. In passing from its circumference over its anterior and posterior surfaces, it leaves between the two lamina an interval, called the *canal of Petit.* It has been generally supposed that this canal does not communicate with the chamber of the eye; but M. Jacobson asserts that it presents a great number of small openings, by means of which, according to him, the aqueous humour can enter in or go out; but I have carefully sought, in vain, to find these openings.

The vitreous humour is surrounded by a membrane called *membrana hyaloidea.* This membrane not only surrounds the humour, but it is divided into innumerable cells, which are filled by it. It is not necessary to say anything of the arrangement of these cells, as this is not of importance in investigating the uses of the vitreous humour.

The eye is not only composed of refracting parts, but likewise of others, which have each a peculiar destination.

The *tunica sclerotica* is a strong fibrous membrane, which constitutes the external coat of the eye. Its evident use is to protect the internal parts of the organ; it likewise serves as a place of insertion to the muscles which move the eye.

The *choroid* coat abounds with bloodvessels and nerves, and is distinctly formed of two laminæ. It is covered with a black substance, which evidently performs an important part in the function of vision.

The *iris* is a small circular part, which may be seen moving behind the transparent cornea. It is of different colours in different individuals, and is pierced in its centre by an opening called the pupil, which enlarges and contracts according to circumstances, which we shall hereafter point out. The *iris* adheres anteriorly, at its curcumference, to the sclerotic coat by a peculiar cellular tissue, which is called the ciliary ligament. The posterior face of the iris is covered by a black substance in considerable abundance. Behind the circumference of the iris are a number of white, radiated lines, which would unite at the centre of the iris if they were prolonged: these are the *ciliary processes.* Anatomists are not yet agreed as to the nature and uses of these bodies. Some consider them nervous, others muscular, and others, again, glandular or vascular. The truth is, at present it is not easy to decide which of these opinions is most probable; and we shall, by-and-by, see that their use is equally unknown.

The colour of the iris depends on that of its tissue, which is variable, and that of its posterior surface, which is of a deep black, and affects the appearance of its anterior face. In blue eyes, for example, the tissue of the iris is nearly white, but the deep black, on the posterior part, modifies this, and determines the colour of the eyes. Anatomists vary in their opinions of the nature of the tissue of the iris. Some consider it similar to that of the choroid

coat; that is, they suppose it to consist chiefly of vessels and nerves; others think they can distinguish a great number of muscular fibres; it has by some been thought a tissue *sui generis;* and by others confounded with the erectile tissue. M. Edwards thinks that he can demonstrate the iris to be formed of four distinct laminæ, of which two are a continuation of the laminæ of the choroid coat, a third pertains to the membrane of the aqueous humour, and a fourth that forms the peculiar tissue of the iris.

It appears from the latest researches respecting the anatomy of the iris, that this membrane is muscular, and that it is composed of two planes of fibres: an exterior, radiated, which dilates the pupil; the other circular and concentric, which closes the pupil. The external circular fibres appear to be supported by a kind of ring which forms each radiated fibre, and in which they glide in the movement of contraction and closing the pupil. The iris receives bloodvessels and the ciliary nerves; the latter are derived from two sources: 1st, the opthalmic ganglion; 2d, the nasal nerve of the fifth pair.

Between the membrana hyaloidea and the choroid coat there is a membrane chiefly composed of nerves. This is known by the name of *retina;* it is nearly transparent, with a very small degree of opacity, of a slight lilaceous tint, and appears to be formed by the expansion of the optic nerve. M. Ribes, however, thinks differently; he supposes it is formed of a distinct membrane, upon which the optic nerve is very freely distributed. He thus establishes an analogy between the retina and the other membranes. There is upon the back part of the retina, about two lines from the optic nerve, a yellow spot, and at the side of this there are several folds. But these appearances are only found in man, and some species of apes. The eye receives a large number of bloodvessels, and many nerves, the greater part of which come from the opthalmic ganglion.

The Optic Nerve.

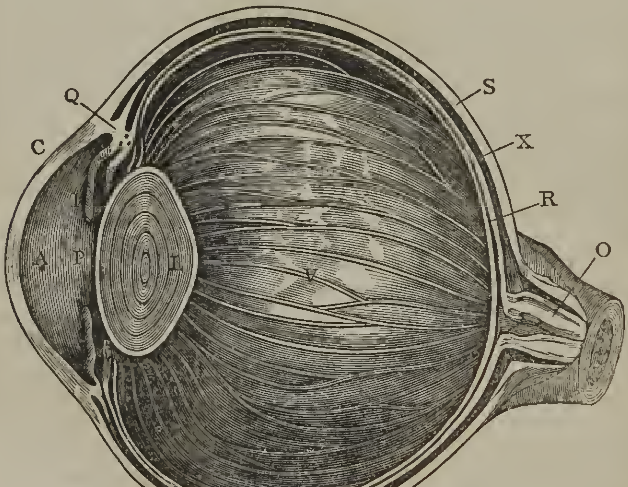
This is the medium of communication between the eye and the brain. It does not arise from the *thalamus nervi optici*, as many anatomists have thought, but it derives its origin, 1st, from the anterior pair of those tubercles called the *quadrugemini;* 2d, from the *corpus geniculatum externum*, an eminence found before, and a little to the outer side of, these tubercles; 3d, from the laminæ of cineritious substance, placed before the meeting of the optic nerves and mamillary eminences, and which is known by the name *tuber cinereum.* The two optic nerves approach each other, and seem to be blended together near the superior part of the sphenoid bone. The most careful researches have been made for the purpose of determining whether they decussate or are in contact, or if they really intermix with each other; anatomy has not yet settled this question, but pathology furnishes proofs of all these opinions. Thus, when the right eye has been long atrophied, the optic nerve of the same side has been known to become so

through its whole extent. In another case, where the right eye was atrophied, the anterior portion of the same side was found in an evident state of disease, and the posterior portion of the left side to present the same appearance. Some have thought that the crossing of the optic nerves in fishes removed every doubt on the subject; but this can only be justly considered as amounting to a probability.

I divided, in a rabbit, the right optic nerve behind the crossing; the consequence was, loss of vision of the left eye. I divided the left nerve; vision was completely abolished. In another animal, I divided, into two equal portions, the crossing over the median line; the animal was immediately deprived of sight. The crossing is then total, and not partial,* as was supposed by the learned Woolaston. Here, as in many other instances, physiological experiment speaks in language clear and positive, when minute anatomy can only raise doubts.

The optic nerve is not formed of a fibrous envelope and of a central pulp, as the ancients believed, but it is composed of very fine filaments, placed at the side of each other, and communicating with each other, like other nerves. This arrangement is very evident in that portion of the nerve which extends from the *sella turcica* to the eye. [The figure beneath represents a horizontal section of the globe of the eye, after Home.

(Fig. 9.)



S represents the sclerotica, the external coat. It is perforated by the optic nerve at O, which is expanded into the retina R.

* In birds the crossing is proved in another manner. I emptied the eye of a pigeon; fifteen days afterward, I found, on examination, that the nervous matter had disappeared, and the nerve atrophied before the crossing, on the side of the emptied eye and on the opposite side behind the crossing. The atrophy extended to the optic tubercle, the point where the optic nerve takes its origin.

The internal or *choroid coat* is indicated at X, and is covered by the *pigmentum nigrum.* Within the *pigmentum nigrum*, and almost in contact with it, the retina R is expanded. Three fourths of the globe of the eye are filled by the vitreous humour, marked V. The crystalline humour, L, is a double convex lens. It occupies the anterior part of the globe, immediately in front of the vitreous humour, which is hollowed out to receive it. The space which intervenes between the lens and the inner surface of the cornea, C, is filled with the *aqueous humour* A. This space is divided into the anterior and posterior chamber by the iris I. The central perforation of the iris, called the pupil, is indicated by P. Q is the ciliary ligament.

The central part of the retina being endowed with the highest degree of sensibility, it is necessary that the images should be made to fall upon this part, and, consequently, that the eye should be capable of having its axis directed to those objects, wherever they may be situated. Hence muscles are provided within the orbit for moving the globes of the eye.

(Fig. 10.)
Muscles of the Eye.

Four of these muscles proceed in a straight course, and are called *recti.* They arise from the bottom of the orbit and the margin of the aperture through which the optic nerve passes, and are inserted by a broad tendinous expansion into the anterior part of the sclerotic coat. Three of them are seen in the diagram, and marked A B C. The margin of the fourth is seen behind and above B. A draws the eye upward, C downward; B and its antagonist move it laterally. There are also two other muscles, which are called *oblique*, S and I, which give the globe some rotation upon its axis. When they act in conjunction, they draw the eye anteriorly, and act antagonistically to the recti muscles. The superior oblique muscle S is remarkable for the manner in which its tendon passes through a sort of cartilaginous pulley, P, in the margin of the orbit, and then turns back to be inserted in the globe of the eye. Thus the action of this muscle produces a motion in exactly the reverse direction in which its fibres contract.

Of the Mechanism of Vision.

Considering the visual apparatus in a physical point of view, we may regard the transparent cornea, aqueous humour, and the crystalline as a compound lens, the different parts of which pos-

sess different refractive properties, inasmuch as they produce natural achromatism. The general cavity of the eye may be regarded as a dark chamber, the choroid being lined with black to prevent the effects of any scattered rays of light upon the image, while the retina presents a surface on which the images are painted; not, however, as in the camera obscura, to be seen by the eyes of others, but to be perceived by the retina itself, and to be transmitted to the brain by the optic nerve. The iris represents a diaphragm destined to limit the field of the lens, to avoid the effects of aberration of sphericity, and only to permit such a quantity of light to penetrate into the eye as will be necessary to paint the object distinctly, without wounding the retina.]

To facilitate the explanation of the manner in which the light enters the eye, let us suppose a single luminous cone passing through the antero-posterior axis of the eye. We perceive at once that there is no other light but that which falls upon the cornea that can assist in vision. That which falls upon the white of the eye, the eyelashes, or the eyelids, can evidently contribute nothing to this effect. It is absorbed or reflected from the different parts, according to their colour. The cornea itself does not receive light through its whole extent, for it is, generally, partly covered above and below by the edges of the eyelids.

Uses of the Cornea.

The convexo-concave form of the cornea indicates the influence which it must exert upon the light that enters the eye. It converges the rays in proportion to its greater refractive power than that of the air. Thus the cornea contributes powerfully to the refraction of the eye; in other words, it increases the intensity of the light that penetrates into the anterior chamber of the eye.

The cornea being very polished at its surface, the light which arrives there is partly reflected, and contributes to give brilliancy to the eye. This reflected light produces the images formed behind the cornea, which thus performs the office of a convex mirror.*

Uses of the Aqueous Humour.

In traversing the cornea, the rays of light have passed from a rarer into a denser medium, consequently they are drawn towards the perpendicular. If they then passed out into the air, instead of entering the anterior chamber of the eye, they would be refracted from the perpendicular, which they had before approached, and, of course, would return to their first degree of divergence. But they enter into the aqueous humour of the eye, a denser medium than the atmosphere, and are, therefore, less refracted from the perpendicular, and, of course, diverge less, than if they had returned into the air.

* I have ascertained, from experiment, that the physical properties of the cornea depend upon the integrity of the fifth pair of nerves. This membrane becomes opaque, and ulcerates after the section of this nerve.—(See *Nutrition.*)

Of all the light entering into the anterior chamber of the eye, that which passes through the pupil alone assists in performing the function of vision. All that falls upon the iris is reflected through the cornea, and enables us to distinguish the colour of the iris. The light does not undergo any new modification in passing through the posterior chamber of the eye, as the medium is still the same.

Uses of the Crystalline Humour.

In passing through the crystalline humour the light undergoes a new modification, which is most important in the function of vision. Philosophers compare the action of this body to that of a lens, the use of which is to collect together the rays of light upon a certain part of the retina. But, admitting that the crystalline possesses all the properties of a lens, it could not fulfil the functions, or, at least, one could not compare the effects to that of a lens used in the air, as its refractive power is nearly the same as that of the aqueous and vitreous humour.* All that can be positively said on the subject is, that the crystalline humour must increase the intensity of the light which it directs to the bottom of the eye in a much greater degree, from the circumstance of the posterior being more convex than the anterior surface. It may likewise be added, that the light which passes near the circumference of the crystalline humour is probably refracted differently from that which passes through the centre.† Of consequence, the dilatation or contraction of the pupil must have an influence upon the mechanism of vision, which appears to deserve the attention of philosophers.

But the crystalline does not produce upon vision the influence long attributed to it, for the function remains after its removal by the operation of cataract. There is another strong proof of this. An artificial eye, made of a globe of glass, over which is fitted a section of another smaller sphere, and which is filled with water to represent the three humours, acts like a true eye, for it forms images on the bottom.

All the light that strikes on the anterior surface of the crystalline does not pass into the vitreous humour, but is partly reflected. A part of this reflected light returns through the aqueous humour and cornea, and contributes to form the brilliant appearance of the eye; another part strikes upon the posterior surface of the iris, and is absorbed by the black matter which is found there. This appears to be indispensable to distinctness of vision. In Albinoes,

* Messrs. Brewster and Gordon have given the following results as the refractive powers of the humours of the eye:

Water being	1.3358
Aqueous humour	1.3365
Vitreous humour	1.3394
Exterior laminæ of the crystalline	1.3767
Central part of the crystalline	1.3990

—(See *Brewster's Journal*, vol. i., p. 49.)

† The structure of the crystalline may have the effect to correct the aberration of sphericity which the common lens produces.

both in man and the inferior animals, in whom both the iris and choroid are destitute of black matter, the vision is always more or less imperfect.*

Uses of the Vitreous Humour.

The vitreous humour possesses a somewhat less degree of refracting power than the crystalline; of consequence, the rays of light which, after having traversed the crystalline, penetrate into the vitreous humour, are drawn from the perpendicular at the point of contact. Its use, then, as respects the direction of the rays in the eye, is to increase their convergency. It may, perhaps, be said that nature might have arrived at the same result by increasing the refractive power of the crystalline humour. But the presence of the vitreous humour in the eye has another and more important use; it is to allow a sufficient extent of expansion of the retina, and thus greatly to extend the field of vision.

M. Lehot, an ingenious and learned natural philosopher, in a series of memoirs on vision, has suggested a singular use of the vitreous humour. He believes that the walls of the hyaloid cells are the places of sensibility to light in the eye, and that the images are not simple surfaces, but figures. But we must confess that his proofs are far from being satisfactory.

What we have thus said of a cone of light passing from a point placed in a prolongation of the antero-posterior axis of the eye, will apply with equal truth to cones passing from every other point towards the eye, with only this difference; that, in the first case, the rays tend to unite at the centre of the retina, while in the other instance they have a tendency to unite at some other point, according to the direction from which they proceed. Thus those which pass from below upward unite at the superior part of the retina, and those which come from above unite at the inferior part of this membrane. The rays of light thus form, at the bottom of the eye, an exact representation of each of the objects which are placed before it, but with this difference, that the images will have a position the reverse of the objects they represent.

Different methods have been had recourse to to establish this point. For a long time experiments were made with eyes artificially constructed. Glass was made to represent the transparent cornea and crystalline humour, and water the aqueous and vitreous humour. Another mode was generally employed before the publication of my memoir "On the Images formed at the Bottom of the Eye." It consisted in placing in an aperture of the window-shutter of a darkened room the eye of some animal, as, for exam-

* Many facts do not agree with this explanation. Most animals remarkable for the excellence of their vision, especially at night, as cats, foxes, horses, many varieties of dogs, and certain fish, have the choroid, and even the posterior face of the iris, of a blue, yellow, or green colour, more or less bright. They reflect the light, like those of cats, in the dark. Thus the bottom of the eyes of these animals is a concave mirror. From the theory of vision, it is not easy to understand how it happens that this brilliancy of the choroid should not injure the function. If, in the construction of our telescopes, we neglected to blacken the internal walls of the tubes, great inconvenience would result.

ple, that of an ox or sheep, having first carefully removed the posterior part of the sclerotica. There could then be seen, very distinctly, upon the retina, the images of objects placed in such a manner as to transmit the rays through the pupil.

I had recourse to a much more convenient method for accomplishing this purpose. I took the eyes of rabbits, pigeons, small dogs, or ducks, in which the choroid and sclerotic coats are nearly transparent; I then removed carefully the fat and muscles, and by directing the transparent cornea towards brilliant objects, I saw distinctly the images of those objects formed upon the retina. This process was known to Malpighi and Haller; the only circumstance peculiar to myself in this respect consists in my having selected for this purpose white rabbits, white pigeons, and white mice; the eyes of Albinoes would probably be found equally good. These will be found much the most favourable to the success of this experiment. The sclerotic coat is thin, and almost transparent; the choroid is equally thin, and as soon as the animal is dead, the blood which coloured it disappears, and ceases to offer any perceptible obstacle to the passage of the light.

The ease and distinctness with which we are thus enabled to perceive the images, suggested to me the idea of making some experiments, which might confirm or invalidate the commonly-received theory of the mechanism of vision.

If we make a small opening in the transparent cornea, and allow a small portion of the aqueous humour to escape, the distinctness of the image becomes lost. The same thing takes place when we suffer a portion of the vitreous humour to escape by a puncture through the sclerotica, which shows that the proportions of the aqueous and vitreous humours are such as to be necessary to perfect vision. I have likewise endeavoured to determine the laws of the dimensions of the image relatively to the distance of the object, and I have found that the size of the image is perceptibly proportional to the distances. M. Biot had the politeness to confirm with me this result, which is likewise conformable to that given by Le Cat, in his "Treatise on Sensations." This author employed artificial eyes in his experiments.

One thing appeared to me worthy of remark in these experiments. In varying the size of the image by moving the object near or to a distance, there was no difference observable in its distinctness. But when a portion of the vitreous humour was removed, the distinctness was manifestly impaired.

I made a small opening at the circumference of the cornea, near its junction with the sclerotic coat, and evacuated all the aqueous humour through this aperture. On presenting the cornea towards a lighted candle, the image appeared to me, other things being equal, to occupy a much larger space than before. The image was evidently less distinct, and formed by a light much less intense than that of the same body seen in the other eye of the same animal, that I had placed in a similar situation with respect to the candle, but which I had preserved whole, for the purpose

of making the comparison. This experiment agrees with what we have before said of the use of the aqueous humour in the mechanism of vision.

The same effect will be produced by removing the cornea. When this is done by a circular incision, made at the point where it unites with the sclerotic coat, the image will not appear to change its dimensions, but the light which forms it loses very sensibly its intensity. We have before remarked that the size of the opening of the pupil probably influences, to a considerable degree, the mechanism of vision. After having removed the cornea, it is easy to enlarge the pupil by a circular incision made into the tissue of the iris; the image in this case becomes enlarged.

As the use of the crystalline humour is to increase the brilliancy and distinctness of the image, diminishing, at the same time, its size, we ought to expect that the absence of this body would produce a reverse effect. When we extract or depress this humour, by a process similar to the operation for cataract, the image is always formed at the bottom of the eye, but it is considerably increased in size. It becomes at least four times larger than that produced in the entire eye, under the same circumstances. The image is likewise very indefinite, and the light produced very weak. Take away from the same eye the aqueous and crystalline humours, and the transparent cornea, and leave nothing, of all the media of the eye, but the capsule of the crystalline lens and the vitreous humour, and it will be found that there is no longer any image formed upon the retina. The light still passes very freely, but it no longer affects a particular form, in relation to that from which it emanates.

The greater part of these results agree very well with the theory of vision generally admitted at the present day. There is, however, one point in which they differ essentially; this is, respecting the distinctness of the image. From theory we are led to infer, in order that the image may be distinct, that it is necessary that the form of the eye should vary, or that the crystalline humour should be carried backward or forward, according to the distance of the object. These changes, which have been assumed actually to take place, have, by turns, been attributed to the compression of the globe of the eye by the recti and oblique muscles which move it, to the contraction of the crystalline humour, or to the action of the ciliary processes. Of late, M. Jacobson has asserted that this effect was produced by the aqueous humour entering or passing out of the canal of Petit. Now experience contradicts this theory, and, of course, all these explanations fall to the ground.

It would be very incorrect, however, to assert that everything took place in the eye of the living precisely as it does in that of the dead animal. There is this essential difference, that in the living animal the pupil dilates or contracts according to the intensity of the light, and, perhaps, according to the distances of objects.

Motions of the Iris.

The circular opening in the centre of the iris, or the pupil, undergoes great variations in its dimensions. Sometimes it is scarcely visible, at others as large as the cornea, the iris seeming to have disappeared. The circumstances which accompany the motions of the iris are,

1st. The different degrees of the intensity of the light; the greater the light, the more the pupil is contracted. When a solar ray enters the eye, the pupil immediately closes; but if we are placed in an obscure light, the pupil becomes dilated.

2d. The nearer an object on which we are looking is placed to the eye, the more the opening of the iris is narrowed. Experiments on this point are delicate, for it is necessary carefully to distinguish that which depends on the variations of intensity of the light from that which is the effect of the distance of the object. This difficulty is the greater, as all the changes of distance are necessarily accompanied with changes in the intensity of the light.

3d. The will has a very limited influence upon the actions of the pupil. This, however, is very slight compared with that produced by light in different degrees of intensity.

The attention we give and the effort we make to see small objects, cause contraction of the pupil. I satisfied myself of this in the following manner. I selected an individual whose pupil possessed great mobility, and there is a great difference in this respect. Having placed before him a sheet of paper, in a convenient position as regarded the eye and the light, and observed the state of the pupil, I then requested the person to endeavour to read some small characters traced upon it, without moving his head or his eyes. Immediately the pupil contracted, and remained so while he made the effort. M. Mille, a young Polish physiologist of great promise, has repeated this experiment in a more rigorous form: his results agree perfectly with mine.

The superior edge of the pupil of the horse is garnished with a black fringe, the uses of which are unknown. Birds appear to possess the power of enlarging or closing the pupil at will.

In order that the iris should contract, it is necessary that the light should penetrate into the eye; if merely directed upon the iris, no motion is determined. The irritation of the iris with the point of a cataract needle does not occasion any sensible motion, as I have repeatedly satisfied myself by experiment.

Messrs. Fowler and Rinhold found that the galvanic excitation directed upon the eye of man and animals caused contraction of the iris. Nysten likewise witnessed the same thing in the bodies of criminals recently executed. I have never repeated this experiment. In living man there is contraction from galvanism, but it differs much from the contraction that galvanism induces in the muscles. The shortening of the fibres is not sudden, but slow and gradual. Applied directly to the iris after death, galvanism does not excite the slightest contraction.

If we divide the optic nerve in a living animal, it becomes dilated and immovable; the same thing takes place in cats and dogs when we divide the fifth pair. In rabbits and Guinea-pigs, on the contrary, the pupil contracts from the section of the latter nerve. The division of the ciliary nerves causes also a cessation of the motions of the iris; Mr. Mayo asserts that the section of the third pair produces in birds, also, immobility of the pupil. Thus it appears that the motions of the iris are subject to much more complicated nervous influences than any other contractile organ. It is dependant on three nerves, the second, third, and fifth pairs. Nevertheless, in the arrangement of the fibres of this membrane, the effect of the will upon its contractions, and the abrupt manner in which they sometimes take place, seem to confound it with muscular motion. But it differs from it in this, that it cannot be excited by direct irritation; and as, after death has been suddenly induced, galvanism excites no motion in the iris, we must infer that the contractions of the pupil are analogous, but not identical with muscular motion.*

The ciliary nerves in man come from two sources. The most numerous arise from the opthalmic ganglion, the others directly from the nasal nerve. It is probable that the first preside over the dilatation, and the second the contraction of the iris. But this is not, at present, fully proved.—(See *Journal de Physiologie*, t. iv.)

Uses of the Motions of the Iris.

The motions of the pupil influence vision in different ways.

1st. They modify the quantity of light that enters the eye.

2d. They influence the number and distinctness of the images formed at the bottom of the organ.

3d. They secure distinct vision at different distances.

Let us examine successively each of these effects.

It is easy to comprehend the advantages of the motions of the pupil with respect to the intensity of the light. It would injure the organ if it did not possess the power of closing itself, so as to receive only the quantity of light necessary to vision, but insufficient to wound it. It is well known that this is accomplished when the light is very vivid. If we look at a bright light, as the sun, the vision is disordered, and the impression painful. The same thing happens when we pass from obscurity, where we have remained for some time, into a bright light; we are dazzled; the pupil becomes strongly contracted. If we are in darkness, the pupil dilates, so as to profit by the little light that may exist. Thus, after having remained for some time in a dark place, we

* It has been observed, that in individuals weakened by venereal excesses, the pupil is very large, as well as in persons affected by intestinal worms, abdominal engorgement, hydrocephalus, &c.; that an application of some of the narcotic plants to the conjunctiva, especially the belladonna, dilates the pupil; that in cerebral affections, the pupil is either very much enlarged or contracted. The motions of the pupil are generally an index of the sensibility of the retina. The consideration of the motions and the state of the pupil is, then, very useful in medicine.

can discover objects, and soon distinguish them sufficiently for ordinary purposes.

When we wish to examine attentively a small object, the pupil diminishes. There is a double advantage in this. In the first place, the contraction of the opening of the eye restricts the number of objects painted upon the retina, the attention so much the less distracted. Again, it is known that an image formed in a dark chamber is more distinct, and, of consequence, more visible, other things being equal, in proportion to the smallness of the opening through which the light enters. According to M. Mille, this result is in part caused by the *diffraction* which takes place at the edge of the pupil when the light passes through it.*

If an object be remote, it is desirable that we should see it distinctly. The attention that we give in looking at it is accompanied with dilatation of the pupil; an effect, however, subordinate to the intensity of the light.

We may infer from the preceding remarks, that the uses of the pupil are to place the eye in relation with the different degrees of intensity of the light and the distance of objects. It is in these motions, and not in the displacements or contractions of the crystalline, that we must seek the reason of our seeing distinctly the same object at different distances. To render this evident, inject a drop of a solution of the extract of belladonna between the eyelids; at the end of a few hours the pupil will become dilated and immovable; this remarkable condition will sometimes remain for several days. It will be thus easy to judge of the influence of the motions of the iris on the habitual use of vision at different distances. These results are the easier to verify, as, in applying the belladonna to one eye only, we can compare it with the other. The following results have been obtained by repeating these curious experiments:

1st. As soon as the pupil is dilated and immovable, objects appear confused and enveloped in a mist.

2d. In using a common lens, we discover that the focus of the eye on experiment is twice as long as that of the eye which remains in its ordinary state.

3d. In proportion as the effect of the belladonna diminishes, these changes in the vision disappear.†

If the pupil be dilated and immovable from any other cause than the belladonna, as *e. g.*, certain diseases, the vision is modified in a manner similar to that described above.

Sir Everard Home cited the case of a young man who, in consequence of paralysis, lost the faculty of adapting his eyes to different objects. It was impossible, for example, for him to read; all the characters were confused; on the contrary, he could distinguish a pin at a distance of ten feet.

* See, on this new question in optics, the learned memoir of this physician in the *Journal de Physiologie*, t. iv.

† I have lately tried this experiment on a myopic young man. As soon as the pupil was dilated, the sight became longer, but he could not see distinctly except at a fixed distance; if closer or more distant, objects appeared confused and misty.

Uses of the Choroid Coat.

The principal use which this serves in vision is absorbing the light, immediately after it has passed through the retina, by means of the black matter with which it is impregnated. The effects found to be produced by a varicose state of the vessels of this membrane must be considered as a confirmation of this opinion. In those individuals who are affected by this disease, the dilated vessels remove the black matter with which it is covered, and every time that the image of the object falls upon that point of the retina which corresponds to these vessels, the object appears to be spotted red. The state of vision in certain white animals, and in Albinoes, where the choroid coat and iris are not coloured black, strongly sustains this assertion. In them vision is extremely imperfect during the day, so that they can scarcely see how to direct themselves.

M. le Cat, and some others, have attributed to the choroid coat the faculty of perceiving light, but this opinion is completely destitute of proof.*

Uses of the Ciliary Processes.

There have been no opinions advanced concerning the use of these parts but what are extremely vague and unsatisfactory; they are generally believed to be contractile. Some suppose that they are destined to move the iris, and others to move forward the crystalline humour. M. Jacobson asserts that their use is to dilate the openings which, according to him, the canal of Petit presents anteriorly, for the purpose of allowing the aqueous humour to enter or be discharged from this canal, which would have the effect to displace the crystalline lens. Some persons imagine that the ciliary processes are secretory organs, for the production of the black pigment found on the posterior surface of the iris and on the choroid coat, or even of a part of the aqueous humour. Mr. Edwards, in a memoir on the Anatomy of the Eye, asserts that they contribute chiefly to the secretion of the aqueous humour, an opinion before advanced by Dr. Young, Secretary to the Royal Society of London, in the Philosophical Transactions. M. Ribes has promulgated a similar opinion, with this difference: "he supposes that the ciliary processes maintain life and motion in the crystalline and vitreous humours." But there are many animals which have no ciliary processes, in which the humours exist. Haller supposed that they preserved the crystalline humour in the most favourable situation. According to this anatomist, they adhere to the capsule of this humour, both at their points and posterior side, by means of the black matter with which they are covered.

* A great number of animals whose sight is excellent have the choroid of vivid or pearly colours.—See *Mem. of M. Desmoulins, Journal de Physiologie*, t. iv.

Action of the Retina.

If we speak here singly of the action of the retina in vision, it is only to facilitate the study of this function. In reality, no distinction exists between the action of this membrane and that of the optic nerve, much less of the sensorium. The action of the retina is a vital action, and its mechanism is completely unknown. The retina receives the impression of light when it exists within certain limits of intensity. A weak light makes no impression upon the retina, and a very strong light disables it from acting. When too brilliant a light strikes suddenly upon the retina, the effect produced is called *dazzling*, and the retina remains for some moments afterward incapable of perceiving the presence of light. This effect is produced by looking steadily at the sun. When we have remained a long time in darkness, even a weak light dazzles us. If the light which falls upon the eye be extremely weak, and if we still endeavour to examine objects, the retina becomes very much fatigued, and we soon feel a sensation of pain in the orbit, and even in the head.

A light, the intensity of which is not very great, but which acts during a certain time on a fixed point of the retina, causes insensibility in that point. If we look for some time at a white spot upon a black surface, and if we then suddenly turn our eyes to a white surfaec, we seem to see a black spot. It is because the retina has become insensible at the point which had been fatigued by looking at the white spot. On the other hand, when the retina has been for a long time without acting in some of its points, while the others have acted, the point which has remained in a state of repose becomes possessed of a much greater degree of sensibility, which causes objects to appear as if they were spotted. We may explain in this manner how it happens that, after having viewed a red spot for some time, white bodies appear spotted with green. In this case, the retina has become insensible to the action of the red ray, and it is well known that, when the red ray is taken from a beam of light, it produces the sensation of green. Similar phenomena occur when we look for some time on a red body, or those of any other colour, and then look suddenly upon white, or other coloured surfaces.

We are enabled to distinguish with great accuracy the direction of the light which is received upon the retina. We believe instinctively that the light passes in a right line, and that this line is a prolongation of that pursued by the ray, which has entered the cornea. Whenever the light, before arriving at the eye, has been modified in its course, the impression produced upon the retina is inaccurate. This is a principal source of those illusions which often take place in vision, and which are therefore called *optical illusions.*

The retina may receive at the same time impressions over its whole extent, but then the sensations which result from them are very imperfect. It can only be strongly affected by the image of

one or two objects, although a much greater number are painted there.*

The centre of this membrane appears to enjoy a more exquisite sensibility than its other parts. It is on this part that we receive the image when we wish to examine an object with attention.

Does light act by simple contact with the retina, or is its peculiar effect produced by traversing this membrane? The presence of the choroid, or, rather, of the black matter covering it, inclines us to the latter opinion. It has been said that the place that corresponds to the centre of the optic nerve is insensible to the impression of light. I do not know of any fact which directly proves this assertion.

All that has been said is exact as regards the phenomena of vision; but, in affirming that they depend upon the retina, we are far from being rigorous, as many new facts, with which the science has become enriched, demonstrate. In the first place, physiologists have agreed to regard the retina as the most sensitive part of the nervous system. The sensibility is so exquisite, they say, that the mere contact of so subtle an agent as light is sufficient to produce an impression. Now I have ascertained, from direct experiment, that the sensibility of the retina is very obtuse, if it exists at all. I have, by means of a cataract needle, lacerated and pricked the retina without producing any obvious effect. The simple contact of a soft body with the conjunctiva causes a much more vivid sensation. Again, so far is the retina from being the prototype of the sensitive organs, that its sensibility may be questioned.†

* In birds of a high flight, whose sight is remarkably powerful, inasmuch as from their cloudy region they perceive and stoop upon their prey, the retina presents a great number of folds perpendicular to its surface; these folds project several lines into the hyaloid humour. Perhaps they give to the bird the faculty of seeing both at a distance and near, as, by a slight motion of the whole of the eye, the animal can make the image fall on points more or less distant from the crystalline; thus the focus may be made to vary to a considerable extent. Birds which fly but little do not have these folds. Birds have another organ not found in other animals: it is membranous, black as the choroid, which passes obliquely from the bottom of the eye, and traverses the central part of the vitreous humour, and is attached to the centre of the crystalline on its posterior face. The uses of this organ (*peigne*) are unknown. I have made some experiments on it. I have remarked that if it is divided, the cornea is no more drawn inward after death. Hence I have concluded that during life the (*peigne*) draws backward the crystalline and cornea, and may thus modify the curve of the latter, and vary the position of the crystalline.

† I have assured myself frequently that pricking and tearing the retina do not cause pain to animals. I have verified in man, in the operation for cataract, by depression, that pressure with the point of the needle upon the retina produces no sensation. If I had observed this result only once or twice, I might still doubt; but I have observed and tried it so often, at the *clinique* of my hospital, that there does not remain the slightest uncertainty. Farther, the part occupied by the retina is the only part that is insensible; for if, in passing over the inner surface of the eye with the cataract needle, it is carried so far forward as to touch the iris, the patient manifests pain. Thus the iris is sensible, but the retina is not. The insensibility of the retina is most remarkable in a philosophical point of view. It shows strikingly the superiority of the experimental method over that which merely uses reasoning, and which supposes that just reasoning will enable us to attain all. What deduction could appear more logical than the great sensibility of the retina! The membrane which is sensible to the presence of light, may be supposed, would be most painfully affected by the contact of a palpable object, and that, if pricked or lacerated, the pain would be exquisite. All this would appear true from reasoning; but a single experiment is sufficient to overthrow this apparently rigorous logic. How many similar reasonings will hereafter disappear before the progress of experimental physiology! *Whatever may be the probability of a fact, let us never neglect to verify it by experiment.*

But is the retina the nervous agent destined to receive the impression of light? According to the ideas which have thus far prevailed, it is difficult to understand how such a question can be asked. Nevertheless, my experiments show that nothing can be more natural. I have divided the fifth pair of nerves in an animal, and it has immediately lost the vision of that side. I have cut that of the opposite side, and the animal became immediately blind. The light of day, nor even a strong artificial light, concentrated with a magnifying-glass, produced the slightest impression. It is not easy to appreciate the trouble this at first caused me, after I had proved it by a great number of experiments. Can it be possible, I said, that the retina is not the principal organ of sensibility of the eye to light? Is it possible that this belongs to the fifth pair of nerves? To satisfy myself, I divided the optic nerve where it enters into the eye. If the fifth pair, or any other nerve, could perceive the light, the section I had made could not prevent it. But it was otherwise; the vision was completely abolished, as well as all sensibility to the strongest light, even that of the sun concentrated by a magnifying-glass. I subjected to this last test an animal in which the fifth pair of nerves was divided. I easily found that if the eye, after having been obscured, was suddenly exposed to the direct rays of the sun, there was an impression, as the eyelid closed. All sensibility, then, is not lost in the retina by the section of the fifth pair; but it is only slight, and that membrane can only concur in vision under the influence of another nerve. We shall see hereafter that it is nearly the same in two other senses.

Action of the Optic Nerve.

There can be no doubt that the optic nerve transmits to the brain, instantaneously, the impressions made upon the retina by the light, but we are absolutely ignorant of the mode in which this is done.

The optic nerve, when subjected to experiment, exhibits the same properties as the retina, with which it is continuous. It is insensible on pricking, cutting, or laceration, and its action in vision is dependant upon the fifth pair. With respect to its crossing with that of the opposite side, no doubt can reasonably exist; the facts that I have reported I consider demonstrative.*

This anatomical arrangement must undoubtedly have a great influence on the transmission of impressions received by the eyes, but it is a difficult point about which to form conjectures that have much probability.

* M. Pouillet, in his *Treatise on Physics*, does not agree in this opinion. He believes that it may be true, perhaps, with regard to animals, but not in man, and that Woolaston has only spoken of the latter. To this I reply, that, with respect to the anatomical arrangements here referred to, man does not differ from the mammiferi. I will add, that, having had occasion to make my objections, in England, to that profound philosopher, whom the intellectual world has so many reasons to deplore, he did not appear to doubt that if the section of the decussation, over the *sella turcica*, produced blindness, it may be concluded that the crossing is total, and not partial. I do not think that he insisted upon his conjecture after the publication of my experiments.

Action of both Eyes.

Notwithstanding what has been said at different periods, and the efforts which have of late been made by M. Gall to prove that we only see with one eye at a time, it appears to me to be demonstrable, not only that both eyes concur at the same time in vision, but that it is absolutely necessary that they should act thus for the perfect performance of certain important acts of this function. There are, however, circumstances in which it is convenient to employ but one eye. For example, when we wish to jugde correctly of the direction of light, to take aim with a gun, or to ascertain if bodies are on a level, or in a right line. There is another situation where it is convenient to employ but one eye: it is when the two organs are unequal, either in refractive power or sensibility. It is for the same reason that we shut one eye when we look through a magnifying-glass.

But, with the exception of these cases, it is much more effectual to use both eyes at the same time. The following experiment of my own appears to me to prove that both eyes see at the same time one object. Receive into a darkened chamber a beam of light upon a plain surface; then take glasses of sufficient thickness, each of which presents one of the prismatic colours, and place them in turn before the eyes. If the sight be good, and especially if both eyes possess equal power, the image will appear of a dirty white, whatever may be the colour of the glass you employ. But if one of the eyes be much stronger than the other, you will see the image of the same colour as the glass. These results have been confirmed in the presence of M. Tillaye, junior, in the cabinet of physic of the Faculty of Medicine. The same object, then, produces two impressions, while the brain perceives but one; but for this purpose it is necessary that the motions of the eye should be in harmony. If, in consequence of disease, the regular motions of the eyes be interrupted, we then receive two impressions instead of one; and this it is which constitutes *strabismus.* We may likewise voluntarily receive two impressions instead of one; we have only to interrupt the harmony in the motion of the eyes to produce this effect.

The harmonious action of the eyes is said to exist in all the red-blooded animals except the chameleon, in which these organs have a separate and independent action; a peculiarity which gives a remarkable expression to the physiognomy of this animal.

On estimating the Distance of Objects.

Vision is essentially produced by the contact of light with the retina, though we are constantly in the habit of referring the cause of the sensation to the bodies from which the light passes, notwithstanding they are at a great distance. It is plain that this must be the effect of an intellectual process.

Our judgment of the distances of bodies is very materially affected by their remoteness. We judge with accuracy when they

are near us; but it is not so when they are very remotely situated; then our judgment is often erroneous; but, when objects are at a very great distance, we are constantly in error.

The united action of both eyes is absolutely necessary to judge exactly of the distances of objects, as may be proved by the following experiment. From a thread suspend a ring, then fix to a rod a hook, which will readily enter the ring. Place yourself at a convenient distance, and endeavour to introduce the hook. If you use both eyes, you will readily succeed at each attempt; but if you shut one eye, and then endeavour to hook the ring, you will fail. The hook will either go beyond or fall short of the ring, and it will only be by accident, and after many fruitless attempts, that the hook will be introduced. Persons whose eyes possess unequal power, will not succeed in this experiment even when they use both eyes.

When a person loses one eye by accident, it often happens that they will not be able to judge accurately of distances for more than a year. I once saw a remarkable case of this kind, where the person, for several months afterward, had to make several attempts before he could seize those objects which were placed even very near to him. Generally speaking, persons who have but one eye judge very inaccurately of distances. The size of objects, the intensity of the light which passes from them, the presence of intermediate objects, &c., influence very much the accuracy of our judgment with respect to the distances of objects. Our judgment is much more exact when the objects are placed on the same plane with ourselves. Thus, when we look from a high tower upon objects situated below, they appear to us much smaller than when they are viewed at the same distance on the same plane with ourselves. The same observation applies to objects placed far above us; and from this we see the necessity of giving a considerable volume to those objects which we place in elevated situations for the purpose of being seen at a distance. The smaller the object, the more necessary it is that it should be placed near to the eye to be seen distinctly. That which may be called *the point of distinct vision*, therefore, varies very much. We see a horse distinctly at thirty feet distance, but we do not see a bird distinctly at the same distance. If we wish to examine a hair or feather of these animals, they must be brought very near to the eye. At the same time, the same objects may be seen with equal distinctness at different distances. For example, it is indifferent to many persons whether they place a book, when reading, at the distance of one or two feet from the eye. The intensity of light thrown upon an object influences very materially the distance at which the object may be seen distinctly.

On estimating the Size of Bodies.

The correctness of our judgment respecting the size of bodies depends more upon sagacity and habit than upon the particular action of the apparatus of vision. We form our judgment of the

dimensions of bodies from the size of the image formed at the bottom of the eye. the intensity of the light which passes from the object, the distance at which we suppose it to be placed, and especially from our habit of seeing similar objects. This is the reason why our judgment of the size of bodies that we see for the first time is so faulty, when we do not know the distance. A mountain, seen at a distance for the first time, appears to us generally much smaller than it really is, because we think it to be much nearer than it actually is. Beyond a very inconsiderable distance, we fall into an illusion which the judgment cannot overcome. That objects at a distance appear infinitely smaller than they actually are, is sufficiently evident from the appearance of the celestial bodies.

On estimating the Motion of Bodies.

We judge of the motion of bodies by that of the image upon the retina, and by the variations in the size of this image; or, what amounts to the same thing, by the change in the direction of the light which arrives at the eye.

In order that we may follow the motion of a body, it is necessary that the image should not be displaced too rapidly, for then we cannot perceive it. This is the case with projectiles thrown by firearms, when they pass very near us; but when they move at a distance, if they be of considerable size, as they are exposed for a much longer time to the eye, the field of vision being greater, we can then distinguish them. To judge correctly of the motion of bodies, it is necessary that we should ourselves be at rest.

We distinguish with difficulty the motion of the bodies which are at a distance, especially if they leave or approach us. Indeed, in this case we can only form our judgment of the motion of the body by the variation in the size of its image. Now this variation being infinitely small, when the body is at a distance it is extremely difficult, and often absolutely impossible, to appreciate it.

Generally, we distinguish with great difficulty, and often we cannot perceive at all, the motion of bodies which are displaced very slowly. This may arise from the real slowness of the motion, as in the case of the hand of a watch, or it may arise from the slowness with which the image moves over the retina, as that of the stars and very distant objects.

Optical Illusions.

From what has been said of the manner that we judge of the distance, size, and motion of objects, it is easy to perceive that we are exposed to numerous errors. These errors are distinguished in science by the name of *optical illusions*. We judge, for the most part, with sufficient accuracy of those objects which are placed near to us, but are frequently deceived with respect to those which are at a distance. The illusions into which we fall with respect to neighbouring objects arise either from the reflec-

tion or refraction which the light undergoes before arriving at the eye, and to that law which we instinctively establish in our own mind, namely, that the light passes from the object to the eye in a straight line. It is to this cause that we must refer the illusions occasioned by mirrors. We see the object behind the mirror in a prolongation of the line that the ray describes in directly approaching the eye. To this cause must be referred the apparent increase or diminution of volume of bodies seen through glass. If the rays are made to converge, the body will appear to us larger; if to diverge, it will appear smaller. The use of these glasses produces another illusion. The objects appear surrounded by the different colours of the solar spectrum, because the surfaces of glass, not being parallel, decompose the rays of light in the manner of a prism.

Distant objects are constantly producing illusions, which we cannot prevent, because they necessarily result from certain laws that govern the animal economy. An object appears so much the nearer to us as its image occupies a more considerable space upon the retina, or as the light passing from it is more intense. Of two objects, of different volume, equally brilliant, and placed at equal distances, the largest will appear the nearest, unless there be some accidental circumstance that enables us to judge more correctly. If two objects of equal volume be placed at equal distances from the eye, but are unequally bright, the most brilliant will appear the nearest. It would be the same if the objects were at unequal distances. This any person may convince themselves of by observing a row of reflectors; if the light of one be more intense than the rest, it will appear to be the first of the row, while that which is really first will appear last, if it be less bright. An object which is so placed as not to have anything between our eye and it, will appear nearer than when this is not the case; the reason of which is, that intermediate objects enable us to compare distances, and thus to form a more exact judgment.

When our eye is attracted by a bright object, while those surrounding it are enveloped in darkness, it appears much nearer than it is in reality. Every one must have noticed this effect of a light at night. Objects appear small according to their distances; thus the trees in a long avenue appear to us to grow smaller and approach each other when they are at a considerable distance. It is by attending to these various sources of illusions, and the laws of the animal economy in which they are founded, that artists are enabled to produce them at pleasure. The painter, for example, in many cases, does nothing more than transfer to his canvass those optical illusions into which we are constantly falling. The construction of optical instruments is also founded on these principles. Some augment the intensity of the light coming from objects; others, by rendering it divergent or convergent, increase or diminish the apparent volume of objects, &c., &c.

There are some optical illusions which we are able to remove

by experience and the exercise of the other senses. The following extremely curious history of a blind man restored to sight, related by the celebrated Cheselden, is strikingly illustrative of this:

"When he first saw, he was so far from making any judgment of distances, that he thought all objects whatever touched his eyes, as he expressed it, as what he felt did his skin, and thought no objects so agreeable as those which were smooth and regular, though he could form no judgment of their shape, or guess what it was, in any object, that was pleasing to him: he knew not the shape of anything, nor any one thing from another, however different in shape or magnitude; but, upon being told what things were, whose forms he before knew by feeling, he would carefully observe, that he might know them again; but, having too many objects to learn at once, he forgot many of them; and, as he said, at first he learned to know, and then forgot, a thousand things in a day. One particular only, though it may appear trifling, I will relate: having often forgotten which was the cat and which the dog, he was ashamed to ask; but catching the cat, which he knew by feeling, he was observed to look at her steadfastly, and then setting her down, said, 'So, puss, I shall know you another time.' He was very much surprised that those things which he had liked best did not appear most agreeable to his eyes, expecting those persons would appear most beautiful whom he loved most, and such things to be most agreeable to his sight that were so to his taste. We thought he soon knew what pictures represented when showed to him, but we found afterward that we were mistaken; for about two months after he was couched, he discovered that they represented solid bodies, when, to that time, he considered them as party-coloured planes, or surfaces diversified with variety of paint; but even then he was no less surprised, expecting the pictures would feel like the things they represented, and was amazed when he found those parts which, by their light and shadow, appeared now round and uneven, felt only flat like the rest, and asked which was the lying sense, feeling or seeing. Being shown his father's picture, in a locket in his mother's watch, and told what it was, he acknowledged a likeness, but was vastly surprised, asking how it could be that a large face could be expressed in so little room; saying, it should have seemed as impossible to him as to put a bushel of anything into a pint. At first he could bear but very little light, and the things he saw he thought extremely large; but, upon seeing things larger, those first seen he conceived less, never being able to imagine any lines beyond the bounds he saw; the room he was in, he said, he knew to be but part of the house, yet he could not conceive that the whole house could look any bigger.

"When couched of his other eye, he says that objects at first appeared large to this eye, but not so large as they at first appeared to the other: and looking upon the same object with both

eyes, he thought it looked about twice as large as with the first couched eye only, but not double."*

This case does not stand alone, but others very similar to it have been witnessed by other surgeons.

A case of this kind occurred in 1819 at the Hôtel Dieu at Paris. The patient was a little girl six years of age, who was sent from the environs of Beaune to be operated on for a congenital cataract of the right eye, the left being in a state of atrophy. The vision was entirely lost; the other senses had acquired a development that supplied the defect. The manner that this child used its senses was remarkable. If called, she accurately distinguished by her ear the point from which the sound came; she went immediately to the place, holding her hands before her as feelers, and lifting her feet high, as if ascending steps, and carefully putting them down, as if to avoid a precipice. If she placed her hand in contact with a body, she generally recognised by the sense of touch; if doubtful, she subjected it to the sense of smell; if she thought it suitable for eating, she applied it to her tongue. This mode of examination she constantly pursued when any one attempted to deceive her; then the vigilance of her senses became doubled, and it was difficult to evade them. But, notwithstanding the extreme susceptibility of her organs of sense, they were only applicable to a very limited range of objects connected with animal life and instinct; the little patient seemed incapable of following a connected chain of reasoning.

She was operated upon successfully. Twelve days after the operation, she could walk about without a guide, and could see sufficiently well not to injure herself. But she had no idea of distances, and reached out her hand for anything that was offered, however distant. It was the same if any one pointed out a particular object; she would reach beyond it, and would seek it by several attempts before attaining it. If a lighted candle was placed before her, she appeared to have great pleasure in looking at it, and following it with her eyes when moved about. If any one placed their hand between her eye and the light, she would immediately endeavour to remove it. In numerous experiments, it was evident that she perceived all the objects presented, but could not distinguish either their colour or form. Various unsuccessful attempts were made to teach her these qualities and make her repeat their names. But at the end of two months after the operation, the power of vision remained nearly the same; no improvement had taken place. It was quite evident that the faculty of vision existed; it only remained to ascertain what prevented the exercise of it.

It was easy to perceive that the child did not *look;* but it is necessary to *look* in order to see. It was necessary, then, to teach her to look; that is to say, to direct her eyes and fix her attention upon objects. This was a tedious and difficult occupation for her,

* I have preferred an abstract of this case in the language of the author to a translation. —*Trans.*

and she made but little progress. It was soon observed that the habit she had acquired of supplying the place of vision by the other senses prevented her making use of it. To make her aware of its value, it was necessary to deprive her of hearing, smelling, and the use of her hands to some extent; especially of the latter, of which she made great use. With this object, her hands were secured behind her back; thus she was compelled to look, to calculate distances, and to guide herself by her eye. Soon she acquired the habit of walking with her head erect, and considerable confidence. These improvements, however, could not conceal the effect of the habit, contracted from infancy, of depending upon the sense of hearing, and which obstructed the attention from that of seeing, and prevented her obtaining the full advantage of it. The use of this sense was therefore suspended by closing the ears, while the hands were kept secured to the back. The deprivation of these two senses seemed to astonish her very much at first; but she soon began to walk about again, and could do so without injuring herself. Wishing to ascertain if any other sense than that of vision had taken the place of touch and hearing, a black bag was placed over her head, releasing her hand and ears. On doing this, she walked with hesitation, and groping her way. It was thus evident that she directed herself by her eyes. Her habits now changed, her relations and wants became multiplied. Before the operation, she remained in bed or in a chair; her movements were without aim, and similar to those of certain animals when enclosed in a narrow cage; but after the operation she insisted on leaving the bed and walking about. Soon she walked about alone, preceded and followed the visiters, mingled with a crowd and disengaged herself from it without using her hands, which were still kept secured behind her back. She knew the other patients, found easily her own bed, sought their society, rendered them small services, appeared to comprehend them, and obeyed their directions, but made no attempt to speak herself. Finally, after two months and a half of careful and persevering attention, she had made so much progress in the education of the sense of vision that she could go alone, without the assistance of her hands, to every part of the hospital, return to her bed, attend to all her wants, and enjoy games before unknown and impracticable for her. This acquisition of a sense before unknown already had exerted an influence over her mind. She was still incapable of maintaining a conversation, but she was susceptible of attention. She was frequently overheard repeating questions that had been addressed to her, or repeating words she had heard. These soliloquies appeared the preludes to conversation, but which she still refused to attempt. It is probable that, by persevering in these attentions, her intelligence might have become developed, but the rules of the hospital not permitting her remaining longer, she was sent back to her friends.

We may draw the following inferences from these facts, viz., that the exact judgment which we become capable of forming of

the distances, magnitudes, and forms of bodies is the result of experience, or, what amounts to the same thing, of the education of the sense of vision. This will be confirmed by considering vision at different periods of life.

Vision at different Periods of Life.

The eyes are early formed in the fœtus. In the embryo, they appear like two black spots; at seven months they become capable of modifying the light, so as to form an image upon the retina, as we know by experiment; until that period they cannot do this, because the pupil is closed by the *membrana pupillaris.** At seven months this membrane disappears. The common mode of expressing this is saying that it is ruptured; it is probably absorbed. At this period the fœtus likewise becomes capable of living independently of the mother; it sometimes happens, however, that no trace of this membrane is found in the eyes of the fœtus at six, or even five months.

There are some points in which the eyes of the fœtus and those of adults differ; they are not, however, very remarkable. In the first, the sclerotic coat is thinner, and even slightly transparent; the choroid is reddish externally, and the black pigment less thick internally; the retina is proportionally more developed, and the aqueous homour is more abundant, which causes the cornea to project; finally, the crystalline humour is much less dense than in the adult. Before birth, the eyelids are closed tightly together, as if they were glued; in some animals they are even united by the conjunctiva of the eyelids, which passes from the one to the other, and is not ruptured until after the birth.

As we advance in life, the quantity of the humours of the eye insensibly diminish until the adult age. After this, they diminish in a manner much more perceptible; this becomes very palpable in advanced age. The crystalline humour, especially, not only becomes more dense, but it begins to lose its transparency, and to assume a yellow colour, which at last becomes quite deep. At the same time that the crystalline becomes yellow, it becomes much more dense, and contracts a slight opacity that may increase with age, until it becomes completely opaque.

Another modification of the eye worthy of remark is this. The choroid is of a brownish black in infants; it is a little less deep at twenty; at thirty it becomes grayish, and it continues to increase with age, so that at eighty years the choroid is nearly colourless.

We learn from experiment that the eye of the newborn infant, then, is very well adapted to act upon the light, and to form ima-

* According to M. Edwards, the membrana pupillaris is formed by a prolongation of the membrane of the aqueous humour, and by the external lamina of the choroid coat. According to this anatomist, there is no aqueous humour in the anterior chamber of the eye before the rupture of this membrane, but this humour is accumulated in the posterior chamber, which proves, 1st, that the membrane of the aqueous humour is not the secretory organ of this fluid; 2d, that this organ exists in the posterior chamber; 3d, that before the seventh month, the membrane of the aqueous humour presents all the characters of a serous membrane, particularly that of forming a sac without an opening.

ges upon the retina. During the first month of its life, however, the infant gives no evidence of its being sensible to the light. Its eyes move slowly, and in a doubtful manner. It is not until the seventh week that it exhibits strong proofs of its sensibility in this respect. Even then it is only attracted by a very brilliant light. It seems pleased to look upon the sun at first, but soon becomes sensible merely to the light of day. In the mean time, however, it seems indifferent to other objects; the first which it notices are generally of a red, or some other brilliant colour. At the end of some days, its attention is arrested by bodies of different colours, but it is a long time before it becomes capable of forming any idea of the distance or size of bodies. It extends its hands to seize even the most remote objects; and, as the first of its wants is food, it endeavours to carry to its mouth everything it gets hold of, whatever may be its nature or dimensions. It appears, therefore, that vision is extremely imperfect during this early period of life; but from exercise, and especially from experience, resulting from continual mistakes, the sight becomes perfected by a sort of education.

It has been asserted that children see objects double and reversed; this assertion, however, is entirely unsupported by any proof. It has been said, also, but without any more reason, that the refracting parts of the eye being more abundant, they see objects much smaller than they actually are. Vision soon acquires all the perfection of which it is susceptible, and in general it undergoes no modification until the approach of old age. It is then that the changes which we have pointed out in the humours tend to render it more distinct; but what principally contributes to this effect is the diminished sensibility of the retina.

Three causes affect vision in old age, viz.: 1st. The diminution of the quantity of the humours of the eye, a circumstance that diminishes the refractive powers of the organ, and prevents the individual from distinguishing accurately near objects. He is obliged, in order to examine them, either to hold them at a distance, so that the light which penetrates into the eye is less divergent, or to employ convex glasses, which diminish the divergence of the rays. 2d. Commencing opacity of the crystalline humour, which weakens the vision, and, increasing, tends to cause blindness, by producing the disease generally known by the name of *cataract*. 3d. The diminished sensibility of the retina, or, if you choose, of the brain, which renders obtuse the perception of impressions produced upon the eye, and often terminates in complete and incurable blindness.*

* Most physiologists consider the diminution of the black tint of the choroid, and the disappearance of the coloured coat from the iris, as circumstances unfavourable to seeing in old age; but, from the researches of M. Desmoulin, it appears that this idea is not well founded. Indeed, in a great number of animals the choroid is totally or partially of a bright or pearl colour, but they are, nevertheless, remarkable for their vision. The pupils in these animals are in the form of a chink or cleft when they are contracted. Such is the case with cats, horses, foxes, &c. If in these animals the brightness and reflection of the choroid concur for the perfection of vision, it would seem probable that the disappearance of the colour from the choroid in an old man would benefit instead of injuring his vision.

Imperfection of Vision.

[*Myopia,* or shortsightedness, arises generally from a congenital malformation of the eye, in consequence of which the refractive power is too great relatively to the distance between the crystalline and the retina. Hence the rays coming from objects placed at a certain distance from the eye form their focus too near to the crystalline, and, consequently, trace upon the retina confused images. This imperfection arises sometimes from too great convexity of the cornea ; but it may depend also upon the state of the interior of the eye, as the form of the crystalline or the density of the humours. Whatever may be the cause, it generally diminishes with age, because the eye, becoming less distended by the fluids, loses a portion of its anterior convexity.

Myopic persons remedy this indistinctness of vision by placing objects very near to the eye, so that the rays which pass from them, being very divergent, form a focus upon the retina. This approximation of objects being always inconvenient, and often impracticable, spectacles, the glasses of which are either plano-concave or bi-concave, are used to obviate the defect. They are more or less curved, the degrees being indicated by numbers. When these glasses are placed before and near the eye, they receive the rays coming from objects, and by their refraction increase the divergence, so as to compensate exactly for the increased refraction of the eye.

Presbyopia, or farsightedness, is seldom congenital, but generally comes on in old age. It is consequent upon such an arrangement of the organ that it only receives distinct images of objects that are very remote, and which send to it rays nearly parallel, while near objects, the rays from which are divergent, form their focus beyond the retina. It is obvious that this affection is the opposite of myopia, and arises from a defective refracting power in the eye, which is generally attributed to a diminution of the humours, in consequence of which there is diminished convexity of the cornea. It is remedied by glasses more or less convex, which, by their refraction, diminish the divergence of the rays coming from near objects, so as to form a focus upon the retina.

Cataract is sometimes a congenital disease, but it more frequently arises at an advanced period of life. It consists for the most part in an opacity of the crystalline, and is developed more or less rapidly. Various ingenious methods have been resorted to by surgeons to remove this obstacle to vision, by extracting or depressing it, when it is often rapidly absorbed. When patients have undergone this operation, and the inflammation that often results from it is completely dissipated, the power of perceiving the light again returns; but they can only distinguish imperfectly, because the eye has lost one of the chief means of making the rays converge upon the retina. Such persons are obliged to use

spectacles which are strongly convex; but even then the vision is rarely very distinct.

In selecting glasses to assist in correcting defective vision, it is of importance that the compensation be not excessive, as its tendency always is to increase the defect. It is better that the curvature of the lens be rather under than too high, especially in myopia, as advancing years tend to correct the defect. The glass should neither magnify nor diminish the object, but only render it more distinct.

Of the nine pairs of nerves that arise from the base of the brain, four are appropriated to the eye; and all, with the exception of the second pair, or optic nerves, are simple motor nerves. Besides these, there are numerous branches of the fifth, and portio dura of the seventh, distributed to this organ. The eyes are intimately connected with the encephalon, not only by the numerous nervous relations of which we have now spoken, and by their proximity, but they also receive branches directly from the anterior cerebral artery.

From the exceeding delicacy and complicated arrangements and relations of these organs, we might anticipate their peculiar liability to disease. Besides the numerous casualties incident to their structure and functions, their close connexion with the brain necessarily implicates them in almost every morbid condition, while their marked influence on the expression of the countenance directs the attention of the physician to them as one of his surest guides in judging of the pathological conditions of the body.* It is manifest that they must directly sympathize in any change in the functions or organic actions of the encephalon. Whatever excites or depresses it will necessarily increase or diminish the innervation of these organs and their appendages, while any change in the circulation of the brain must necessarily extend to, and have a corresponding effect upon, the eyes. Thus, in health, we may read the state of the mind, and almost every passing emotion, in the expression of the eyes. In disease, their dulness and insensibility, or their restlessness and morbid excitement, afford indications of the state of the encephalon, which cannot be readily misunderstood. Their contracted pupils, redness, fierceness, and extreme sensibility to light, so common symptoms in the earlier stages of the severer forms of the idiopathic fevers and some other diseases, mark with certainty the tendency to, or actual existence of, inflammation in the cerebral textures; while their languid expression, expanded iris, musci volitantes, and loss of consentaneous motion, show with equal certainty loss of power in the great centre of the nervous system. Again, intense and long-continued use of the eyes not only induces redness in these organs themselves, but, from the cephalalgia and vertigo which are so apt to ensue, no doubt, also, hyperæmia of the encephalon.

* Hippocrates remarks, "Ita valet corpus sicuti valent occuli: cum illi bene videntur valere—corpus valet."—*Epidemics*, lib. iii.

Amaurosis generally affects the whole of the retina; occasionally, however, it confines itself to one or more parts, and thus produces some remarkable anomalies. Thus blank spots appear in the field of vision: when the paralysis is confined to certain points of the retina, or if considerable portions, say one half, of the membrane be diseased, the individual sees only parts of objects. Amaurosis may arise from the morbid condition of the retina, the trunk of the optic nerve, or a portion of the brain. It not unfrequently arises in one eye, while the other remains perfect; sometimes occurring without pain, or even the consciousness of the individual, a knowledge of its existence being revealed to him, perhaps, in accidentally shutting the well eye to examine an object with the other. Partial and temporary paralysis, causing indistinctness of vision, musci volitantes, &c., not unfrequently arises from sympathy with the disordered state of the stomach.]

CHAPTER IV.

OF HEARING.

HEARING is the function by which we are made acquainted with the vibratory motions of bodies. *Sound* is to hearing what light is to vision. Sound is the result of an impression produced upon the ear by the vibratory motion impressed on the particles of bodies, by percussion or any other cause. This word describes also the vibratory motion itself. When the particles of a body have been thus put in motion, they communicate it to the elastic bodies which surround them; these act again in the same manner, and thus the vibratory motion is propagated, oftentimes to a considerable distance. Elastic bodies alone, generally speaking, are capable of producing and propagating sound. For the most part, solid bodies produce it, while the air is often the vehicle which transmits it to our ear.

We may consider it according to its *intensity*, *note*, and *tone*.

The *intensity* of sound depends on the extent of the vibrations.

The *note* depends on the number of vibrations in a given time, and is divided into *sharp* and *grave*. A *grave note* arises from few vibrations; in a *sharp note* they are very numerous. The most grave note that the ear can perceive is formed by thirty vibrations in a second; the most sharp, by twelve thousand. But M. Savart has proved, by a series of experiments and ingenious instruments, that the ear can appreciate sounds when there are 48,000 vibrations in a second.* Between these two extremes are included all appreciable sounds, that is, all sounds of which the

* See *Annal. de Physiologie et Chimie, Octobre,* 1830.

ear instinctively perceives the vibrations. *Noise* differs from an *appreciable sound* in this, that the ear cannot distinguish the number of vibrations of which it is formed.

An appreciable sound, which is composed of double the number of vibrations of another sound, is called its *octave.* Between these two are seven intermediate sounds, called the *diatonic scale,* or *gammut;* they are distinguished in France by the names *ut, re, mi, fas, sol, la, si.*

When we put in motion a sonorous body, by percussion, we hear at first one distinct sound, more or less intense, or more or less sharp, as the case may be. This is the *fundamental sound.* With a little attention, one perceives that it produces at the same time other sounds; these are called *harmonics;* this will be readily observed by striking the chord of an instrument.

The *note* depends on the nature of the sonorous body, and also upon the greater or less number of harmonics produced at the same time as the principal sound.

Sound is propagated by all elastic bodies. The velocity with which it moves varies according to the body that serves to propagate it; it moves through air at the rate of a thousand and forty-two feet in a second; its transmission is still more rapid through water, stone, wood, &c.* It generally loses its force in passing, in a proportion which is directly as the squares of the distances. This, however, is only in passing through air; sometimes its intensity is increased in passing; this is the case when it traverses very elastic bodies, as certain metals, wood, condensed air, &c. Sharp, grave, intense, and weak sounds are propagated with equal rapidity, and without being confounded. It has been generally supposed that sound is propagated in a right line, forming cones analogous to those of light, with this essential difference, that cones of sound have only an oscillatory motion, while those of light are progressive.

When a chord is in unison with another chord, that is, when it produces the same sound if put in vibration in the same manner, it presents a remarkable property: it vibrates and produces its peculiar sound, if this sound is produced in its neighbourhood. This property of the unison of chords has been long understood, but it was not so well known that all bodies are susceptible of vibrations, and of presenting phenomena analogous to those of chords.

M. Savart has shown, by a series of ingenious experiments, that all elastic membranes, dry or humid, vibrate and transmit sound if the sonorous vibrations are heard near these membranes, without their being in unison with the bodies which produced the vibrations. M. Savart has also proved that the different degrees of tension of membranes, their thickness, homogeneity, humidity, &c., have a remarkable influence on the facility with which they vibrate by communication; but that, whatever may be their state, they vibrate always in unison with the sound produced. This law

* Vide Memoirs d'Arcueil, vol. ii.

is also common to all bodies. These experiments are the more interesting, as the greater part of the organs of hearing is composed of elastic membranes and laminæ, as we shall now see.

When sound meets with a body that opposes it, it is reflected in the same manner as light, that is, the angle of incidence is equal to the angle of reflection. The form of the body which reflects sound has a similar influence. The slowness with which sound is propagated produces certain phenomena, the reason of which may be easily explained; such, for example, as echo, the mysterious chamber, whispering gallery, &c.

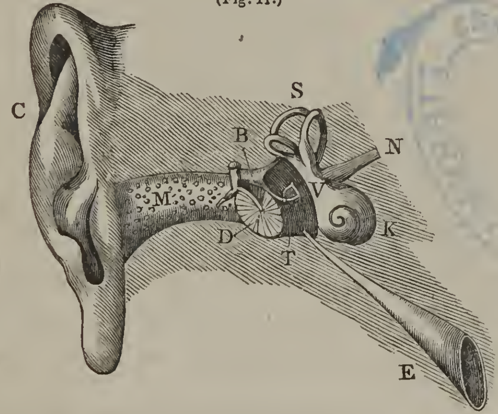
Apparatus of Hearing.

This organ is very complicated, but we shall not enter into minute anatomical details, for at present we know but little of the uses of the different parts that constitute this apparatus.

As in the apparatus of vision, so in that of hearing, we find a collection of organs, which concur in their physical properties, and behind them a nerve destined to receive and transmit impressions. The apparatus of hearing is composed of the external, middle, and internal ear, and auditory nerve.

[The following diagram will give an idea of these different parts:

(Fig. 11.)



C is the external cartilage. M the *meatus auditorius externus.* B is the middle ear. It consists of the membrana tympani D, by which the external is separated from the middle ear; the chain of small bones, B, by which the tympanum is connected with the fenestra ovalis. T is a hollow space, called the cavity of the tympanum, of an irregular shape, and scooped out of the petrous portion of the temporal bone. E is the eustachian tube, or meatus auditorius internus, which begins in the cavity of the tympanum, of a small size, and enlarging as it extends, opens at the back part of the nostrils. The internal ear consists of the parts indicated by V S K, the labyrinth: the first, V, is called the vestibule; S, the semicircular canals; K, the cochlea; N, the auditory nerve.]

External Ear.—We shall comprehend under this denomination the external cartilage, and the *meatus auditorius externus.*

External Cartilage.—The size of the external cartilage is different in different individuals. The external face, which in a well-formed ear projects a little forward, presents on its anterior surface five eminences, called the helix, ante-helix, tragus, ante-tragus, and the lobule. There are likewise three cavities, viz., that of the helix, the scapha, and the concha. This cartilage is very elastic; the skin which covers it is thin and dry, and is attached to the cartilage by a strong cellular tissue, which contains but little adipose substance, but the lobule contains a large quantity. Beneath the skin is seen a large number of sebaceous follicles, which furnish a white and shining matter, which gives to the skin its polish, and, perhaps, a part of its flexibility. There is likewise seen on the different prominences a few muscular fibres. This part receives many nerves and bloodvessels, is very sensible, and easily becomes red. It is attached to the head by ligaments of cellular tissue, and muscles called, according to their positions, anterior, superior, and posterior. These muscles are very much developed in many animals, but in man they can only be considered as *vestiges.**

Meatus auditorius externus.—This part extends from the concha to the membrana tympani, its length varying according to the age; in the adult it is from ten to twelve lines. It is narrowest at the middle part, and is slightly curved upward and forward. At its external orifice it is furnished with hairs, like the entrance to the other cavities. It is composed of bone, and a fibro-cartilage, which is confounded with the external cartilage, and a fibrous part which completes it above; the *skin* with which it is covered is thin, and is expanded over the external surface of the *membrana tympani.* Beneath this skin there are a great number of sebaceous glands, which secrete the *cerumen*, or wax—a yellow, bitter, and unctuous substance, the uses of which will hereafter be pointed out.

Middle Ear.—The middle comprehends the cavity of the tympanum, the small bones contained in it, the mastoid cells, and the eustachian tube, &c.

The *tympanum* is the cavity which separates the external from the internal ear. Its form is that of a portion of a cylinder, somewhat irregular. Its internal wall presents above an oval hole, called the *foramen ovale*, which communicates with the vestibule, and is closed by a membrane; immediately below is a small projection, and beneath this a cleft, in which is lodged a nervous filament; still lower, there is a round opening called the *foramen rotundum*, which corresponds to the external *scala* of the *cochlea*, and is also covered by a membrane. The external opening of

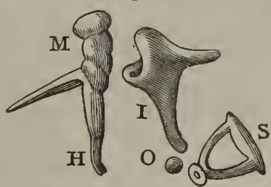
* The name *vestiges* is given by the French anatomists to those parts of animals which are without any perceptible use, but which seem only intended to indicate the uniform plan that nature has pursued in the construction of animals.

the tympanum is covered by a membrane called the *membrana tympani.* This membrane passes obliquely downward and inward; it is tense, very thin, and transparent; it is covered externally by an expansion of the skin, and internally by a mucous membrane, which lines the tympanum; it is also covered on this side by a nerve, called the *cord of the tympanum;* its centre gives attachment to the handle of the *malleus;* its circumference is attached to the osseous extremity of the *meatus auditorius externus*, and it adheres firmly at every point, affording no opening by which the external and middle parts of the ear can communicate with each other. Its texture is dry, fragile, and has nothing analogous to it in the animal economy; there cannot be distinguished about it either fibres, or bloodvessels, or nerves.

The circumference of the tympanum presents anteriorly, 1st. The eustachian tube, by which the tympanum communicates with the superior part of the pharynx. 2d. The opening by which the tendon of the internal muscle of the *malleus* enters. Posteriorly is seen, 1st. The opening into the mastoid cells, which are irregular cavities always filled with air, opening into the thickest part of the mastoid process. 2d. The pyramid, a small hollow projection, which gives attachment to the muscle of the *stapes.* 3d. The opening by which the *cord of the tympanum* enters into this cavity. Below there is a small cleft called "*gleniodale,*" by which the tendon of the anterior muscle of the malleus enters, and the cord of the tympanum passes out to anastomose with the lingual nerves of the fifth pair. Above there is nothing but small openings through which bloodvessels pass. The tympanum, and all the openings with which it abounds, are covered by a very delicate mucous membrane. This cavity is always filled with air, and contains four small bones, viz., the *malleus*, the *incus*, the *os orbiculare*, and the *stapes*, which are so connected together as to form a chain, extending from the *membrana tympani* to the *foramen ovale*, where the base of the *stapes* is fixed.

[In the following figures these four bones are distinctly delineated:

(Fig. 12.)



These minute bones are sometimes called the *tympanic ossicula;* they are here magnified, and represented separately. The first, M, represents the *malleus*, or hammer; the second, I, is the *incus*, or anvil; the third is the smallest bone in the body, being about the size of a millet seed, called the *os orbiculare;* and the last, S, the *stapes*, or stirrup. In the preceding figure, these minute bones are placed in situ naturale. The malleus, with its long handle, is

seen at B, attached to the *membrana tympani*, and the stapes with its base attached to the fenestra ovalis. These minute bones are regularly articulated, with all the arrangements of other joints, and are moved by small muscles provided for the purpose. Their office is obviously to transmit the vibrations of the tympanum to the fenestra ovalis, probably at the same time increasing their force.] There are small muscles destined to move this chain, and to stretch and relax the membranes to which it is attached. Thus the internal muscle of the malleus draws it anteriorly, moves the whole chain of small bones, and stretches the membranes. The anterior muscle produces an opposite effect. We may suppose, also, that the small muscle lodged in the pyramid, and which is attached to the neck of the stapes, may produce a slight tension upon the chain, drawing it towards itself.

Internal Ear or Labyrinth.—This is composed of the cochlea, the semicircular canals, and the vestibule.

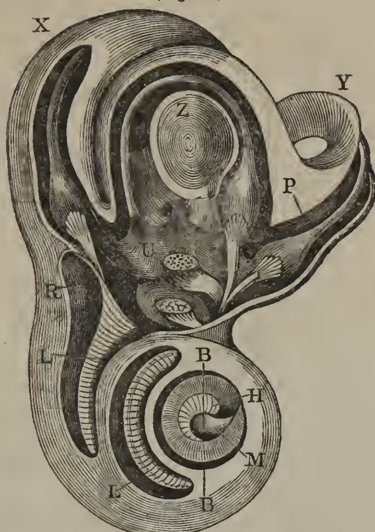
[In the following figure there is a magnified view of *the labyrinth:*

(Fig. 13.)

It consists of the middle portion, called the vestibule, V, from which arise the three semicircular canals, X Y Z. To the lower side of the vestibule is attached a spiral canal, resembling the shell of a snail, called the cochlea, and marked K. The letter O points out the foramen ovale, and R the foramen rotundum. All these bony cavities are lined with a very delicate membrane, called the *membranous labyrinth*, and are filled with a thin gelatinous fluid, formerly called the *fluid of Cotunnius*, who first described it: it has been recently termed the *perilymph* by M. Breschet. The membranous labyrinth floats in the perilymph, the auditory nerve being expanded upon it. The fenestra ovalis and the foramen rotundum, O and R, are covered with a membrane, and open into the cavity of the tympanum, the former having the bone of the stapes attached to it, as seen in figure 11, at T.

The following figure, which is on a still larger scale, is taken from Breschet.

(Fig. 14.)



The osseous labyrinth is laid open, so as to show the parts it encloses, more particularly the *membranous labyrinth*, floating in the *perilymph*. The cochlea is seen to consist of the spiral convolutions of a double tube, or, rather, one tube separated into two compartments by a partition, L L, called the *lamina spiralis*. These compartments are called the *scalæ* of the cochlea. One of these compartments arises from the vestibule, and the other commences at the inner side of the membrane, which closes the *foramen rotundum*.

All these cavities of the internal ear are contained in a very hard bone, called, from this circumstance, the *os petrosum*.

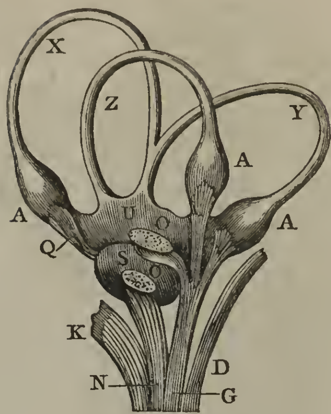
On the next page is a view of the membranous labyrinth removed from the bony cavity represented in the last figure, and in a corresponding position, the same letters indicating the different parts in both figures.

By comparison, the correspondence between the two figures is readily recognised.

X Y Z correspond to the semicircular canals; each present at their origin from the vestibule a considerable dilatation, termed an *ampulla*, marked A A A.

X and Y are united. U S is the membranous vestibule, which is not an exact representation of the osseous cavity. It consists of two distinct sacs, opening into each other, of which U is called the *sacculus vestibuli*, the *median sinus*, or *utricle;* the other, marked S, the sacculus. They contain within a small mass of white calcareous matter, resembling powdered chalk, as it were suspended by numerous nervous filaments arising from the accoustic nerves G N. This is observed in all the mammalia, and is no doubt important in the function of hearing. G is the anterior

(Fig. 15.)



trunk of the auditory nerve, N the posterior trunk, D the portio dura; K is a branch of the auditory nerve.]

The fluid of Cotunnius is very near to the cephalo-spinal fluid at the orifice of the internal auditory passage; but it does not appear that these two fluids communicate: at least my researches on this point have not led to this result.

Auditory Nerve.—This nerve arises from the fourth ventricle of the brain; it enters into the labyrinth by foramina at the bottom of the *meatus auditorius internus.* Having arrived at the vestibule, it is divided into several branches, of which one remains in the vestibule, another enters the cochlea, and two are distributed through the semicircular canals. The manner in which these different branches are arranged in the cavities of the internal ear has been described, with great care, by Scarpa. It would not be proper to enter here into a more minute detail.

In terminating this very concise description of these parts, it will be proper to remark, that the internal and middle ear are traversed by several nervous filaments, which probably have some influence in the function of hearing. For example, the facial nerve passes through a canal hollowed out from the os petrosum. In this canal it receives a filament of the vidian nerve, and it supplies the cord of the tympanum, which is spread over this membrane. Many other anastomoses are likewise seen in the ear, to which the attention of anatomists has been called by M. Ribes, M. Jacobson, and M. Breschet.

Recent experiments have taught us that the ear, as regards its sensibility, presents physiological circumstances analogous to those of the eye. The membrane which lines the auditory passage possesses extreme sensibility; this is very apparent at the entrance of this passage. The slightest contact of a foreign body excites vivid pain; physicians have always noticed the exquisite sensibility consequent upon inflammation of this part. From this, it is very probable that the sensibility of the tympanum is still

more exquisite, and that it would be at its maximum in the cavities of the labyrinth. But this is not the case: as in the eye, the greatest sensibility exists about the exterior part of the apparatus. This property is very obtuse about the tympanum, and the auditory nerve may be touched, pricked, and torn in animals, without any apparent indication of sensibility. In this respect it is in striking contrast with the fifth pair, which may be said to be in contact with the auditory nerve at its origin, which cannot be even slightly touched without producing the most acute pain. In this respect the nerve of hearing resembles that of vision.

Mechanism of Hearing.

Use of the External Cartilage of the Ear.—It collects together the sonorous rays, and directs them towards the meatus auditorius externus; this it more effectually does from its size and elasticity, and from its being detached from the head and directed forward. Boerhaave pretended to have proved, by an elaborate calculation, that all the sonorous rays which fall upon the external surface of the cartilage are necessarily conducted towards the auditory opening. This assertion is, however, evidently incorrect, at least in some individuals, because, in some instances, the antehelix is more prominent than the helix. As all the rays are to be directed towards the concha, what will become of those that fall on the posterior part of the antehelix in these cases? It is much more probable that the external cartilage, from its great elasticity, which may, perhaps, be somewhat modified by the intrinsic muscles, is capable of entering into vibrations through the influence of the sonorous undulations impressed upon the air. With respect to the inequalities of its surface, it appears from M. Savart that, according as a membrane is or is not parallel to the surfaces of bodies which vibrate near it, its oscillations are more or less distinct, parallelism being the most favourable circumstance. This cartilage, however, is not absolutely necessary to the function of hearing; for in man, and some animals, it may be removed without the hearing being impaired for more than a few days.

Uses of the Meatus Auditorius Externus.—This transmits sound to the membrana tympani, like any other tube, partly by its walls, and partly by the air contained in it. The hairs which are placed at its entrance, and the cerumen, prevent the introduction of foreign bodies, such, for example, as grains of sand, dust, or insects, &c.

Uses of the Membrana Tympani.—This membrane receives the sound transmitted to it through the auditory opening. It separates the meatus auditorius externus from the tympanum. It is stretched tight, is thin and elastic, and of a uniform thickness. It is therefore thrown into vibrations by the sonorous undulations conducted to it by the air or its walls. But, from a very simple experiment of M. Savart, it appears that it is especially the air which puts it in vibration.

This learned philosopher placed at the upper part of a truncated cone, made of paper, a delicate membrane, which closed the opening, very much, as the *membrana tympani* closes the auditory passage. He then produced sounds near the walls, exterior to the cone; the membrane vibrated but little. But if he produced the same sounds at the base of the cone, so that they were transmitted to the membrane by the interior air, the vibrations were much more distinct, even at the distance of 100 feet.

The mode of insertion of the muscles of the malleus into this little bone, and of its attachment to the *membrana tympani*, indicate clearly that it has different degrees of tension. It would be absurd to suppose that this little membrane places itself in unison with the innumerable sounds that our ears perceive. But it is more than probable that in certain cases it is stretched by the internal muscle, and in others relaxed by the anterior muscle of the malleus. Heretofore these have been merely conjectures, but some experiments of M. Savart appear to have unveiled the truth.

When a thin membrane is stretched very tight, it vibrates with difficulty; that is, the motions of the vibrating parts are very slight. It is the reverse when the membrane is relaxed; and as it is proved directly by experiment that the membrana tympani in place vibrates in consequence of the sonorous undulations which reach its surface, it cannot be doubted that, the more it is stretched, the less will be the extent of its vibrations. It is highly probable, therefore, that it is relaxed for weak or agreeable sounds, and tightened for intense or disagreeable sounds. An opening made into this membrane does not very essentially impair the hearing.* As it is dry and elastic, it is peculiarly adapted to the transmission of sound to the air contained within the tympanum, and to the chain of small bones. The cord of the tympanum will necessarily participate in the vibrations, and transmit to the brain certain impressions. The contact of a foreign body with this membrane is exceedingly painful; a violent noise also occasions severe pain in this part. The membrane of the tympanum may be torn, or even entirely destroyed, without the hearing being essentially impaired.

Uses of the Cavity of the Tympanum.—Its principal use is to transmit to the internal, the sounds which it has received from the external part of the ear. This transmission of sound by the tympanum takes place, first, by the chain of small bones, which acts particularly on the membrane of the foramen ovale;† second, by

* For the various opinions which have been formed concerning this membrane, see the works of Haller, vol. v.

† We are ignorant of the use of those motions which are produced by the chain of small bones. However, as all these little bones are united together, the first in contact with the tympanum and the last with the fenestra ovalis; as, besides, the malleus can move itself, it appears to me it was indispensable, to prevent laceration, that the chain should be composed of a number of pieces movable upon each other. Again, it appears to me that when the malleus is drawn within, the motion extends to the stapes, which compresses the fluid contained within the labyrinth; and from this it must result, that the amplitude of the oscillations of the membrane of the fenestra rotunda will become less. In a word, I believe that the chain of small bones is to the ear what the sounding part is to the violin. The loss of these bones, except the stapes, does not necessarily occasion deafness; we have remarked, however, that those individuals who are in this situation only preserve this sense for two or three years.

the air which fills it, and which acts upon the whole of the os petrosum, but especially upon the membrane of the foramen rotundum; third, by the vibration of its walls. There appears to be no doubt that one of the uses of the tympanum is to keep before the fenestra rotunda a peculiar atmosphere, the properties of which are nearly constant, inasmuch as this small mass of air is preserved continually at the same temperature by the surrounding bloodvessels. Without this precaution, the membrane of the fenestra rotunda would deteriorate soon, which must happen when the membrana tympani is freely perforated.

Use of the Eustachian Tube.—This serves to admit the external air, so that the pressure on both sides of the membrana tympani being equal, of course no obstacle is offered to the vibrations of the membrane, by which sound is transmitted to the internal parts of the ear. The obliteration of this tube is a frequent cause of deafness. It has been supposed that this tube assists in conducting the sound to the internal parts of the ear, but this is a mistake, there being nothing to support the assertion. It allows the air to escape from the tympanum when the atmosphere has been violently agitated by a loud noise, and afterward admits it to this part, and to the mastoid cells. The air in the tympanum, being very much rarefied from the heat of the body, diminishes the intensity of the sound which it transmits.

Uses of the Mastoid Cells.—This is a point which is not well ascertained. It is supposed that they assist in augmenting the intensity of the sound which arrives at the tympanum. If they produce this effect, it must be rather by the vibration of the laminæ which separate the cells, than by that of the air which they contain. Sound may reach the tympanum otherwise than by the *meatus auditorius externus.* The sounds which strike upon the bones of the head may be directed towards the temporal bone, and the percussion thus arrive at the ear. We all know how distinctly the noise arising from the machinery of a watch is perceived by placing it in contact with the teeth.

Uses of the Internal Ear.

We are but little acquainted with the functions of the internal ear. We suppose that the sonorous vibrations are propagated in various ways, but principally by the membrane of the fenestra ovalis, that of the foramen rotundum, and by the internal parietes of the tympanum, and that the fluid contained within the cavities of the internal part of the ear, sometimes called the fluid of Cotunnus, must receive vibrations, which it transmits to the auditory nerve. We may likewise suppose that this fluid performs the extremely important function of breaking the impulse of very intense vibrations, which would otherwise essentially injure the auditory nerve. It is probable that, in this case, the fluid flows back into the aqueducts of the cochlea and vestibule, which, according to this view, have considerable analogy in their functions with the eustachian tube.

The external scala of the cochlea must receive vibrations, principally, by the membrane of the foramen rotundum; the vestibule, by the extremity of the chain of small bones; the semicircular canals, by the walls of the tympanum, and perhaps by the mastoid cells, which are often prolonged beyond these canals. We are, however, absolutely ignorant of the precise share which each of the internal parts of the ear take in performing the function of hearing. The osseo-membranous partition which separates the two scalæ of the cochlea has given rise to an hypothesis which no one believes at the present day.

Action of the Auditory Nerve.

This nerve receives impressions and transmits them to the brain, which perceives them with a greater or less degree of exactness in different individuals; but this action is itself influenced by the fifth pair; when the latter nerve is divided or diseased, the hearing is weakened, or even abolished. Many persons are said to have a false ear, that is, they are incapable of accurately distinguishing sounds. We cannot explain the action of the auditory nerve, nor that of the brain in hearing, but many observations have been made on this function.

A sound, to be distinctly perceived, must range within certain limits; if it be too violent, it gives us pain; if too weak, it causes no sensation. We may perceive a great number of sounds at a time. Appreciable sounds combined, and succeeding each other in a certain manner, are a source of agreeable sensations. There is one art, the object of which is to arrange sounds in such a manner as to produce this effect; this art is *music*. To an ear so organized as to be able to appreciate it, music is undoubtedly the first of arts, for there is no one that is a source of such vivid and delightful sensations, that excites more enthusiasm, or leaves behind it deeper or more agreeable recollections. Certain combinations of sounds, on the contrary, cause disagreeable sensations. Very sharp sounds wound the ear, and those that are very intense and grave lacerate the membrana tympani. The absence of the fluid of Cotunnus from the cavities of the internal ear destroys hearing. When a sound has been long continued, we often think that we continue to hear it even after it has ceased.

As persons born blind have had their vision restored at an age when they could describe their sensations, so those born deaf have acquired the sense of hearing at an age when they could comprehend the immense advantage of acquiring a new sense. Science possesses at present many examples of this. They are not less interesting in a physiological than a philosophical point of view. Such is the following history, the authenticity of which has been established by the Academy of Sciences of Paris.

Louis-Honoré Tresel, aged ten years, born at Paris, of poor parents, was born deaf; he could not hear the loudest sounds. His physiognomy had little expression; he dragged his feet, his gait was unsteady, and he was incapable even of using his hand-

kerchief. Hearing was restored to him by means of an operation invented by a blind man, who, tired of his situation, and of the useless attempts of medical men to relieve him, succeeded in curing himself. This operation consists in injecting air and various liquids into the tympanum through the eustachian tube. The first days that followed the development of his sense of hearing were to Honoré days of delight. All sounds, noises even, caused him ineffable pleasure, and he sought them with avidity. He was thrown into a sort of ecstasy on hearing a musical snuffbox. But it required some time for him to perceive that speech was a means of communication. Still he did not at first attend to the sounds, but to the motion of the lips which accompanied them, and to which before he had paid no attention. For several days he believed that a child of seven months spoke, because he saw it move its lips. He was made acquainted with his mistake, and from that time he began to perceive that it was the sounds that were important, not the motion of the lips which accompanied them. Hearing a magpie pronounce some words, he at once concluded that all animals possessed the power of speech, and tried to make a dog to which he was much attached speak to him. He had recourse to violence to make him say " Papa ! give me some bread," the only words he could pronounce himself. The loud cries of the animal frightened him, and he gave up the singular undertaking.

A month passed; and still Honoré remained nearly at the same point, absorbed by his sensations and his new remarks; he could not get hold of syllables which form words. It required a period of nearly three months to comprehend words with several syllables, and the meaning of some simple and short phrases. It required also a long time to recognise the direction of sound. A person having concealed himself in a chamber in which the child was sitting, called to him: it was with great difficulty he succeeded in finding the place from which the voice came.—(*See the end of this case in the article on the Relations of Hearing and the Voice*).

Action of both Ears.

We receive two impressions from sound, but only perceive one. It has been said that we never use but one ear at a time, but this is incorrect. It is true, that when sound arrives directly at one ear, it is received with more facility by that, and more imperfectly by the other, and in this case we only use one ear. When we wish to listen attentively to sounds which we fear to lose, we place ourselves in a situation that the sonorous rays may enter directly into the concha of one ear; but when we wish to determine from what point sound proceeds, and in what direction it comes, we are obliged to use both ears, because it is only in comparing the intensity of the two impressions that we are able to distinguish the side from which the sound comes. If, for example, we stop one ear, and another person makes a slight noise at some distance, it will be impossible for us to determine the di-

rection of the sound, though we should succeed every time with both ears. Sight greatly assists us in judging of sounds, for in profound darkness, even with both ears, it is often impossible to decide from what point a noise comes.

Sound also enables us to judge of the distance by which we are separated from bodies which produce it. But, in order that our judgment may be correct in this case, it is necessary that we should be familiar with such sounds, otherwise our judgment will be always erroneous. In this case, our judgment is formed on the following principle, viz., that a very intense sound comes from a neighbouring body, and a very weak sound from a distant body. If it should happen that the intense sound comes from a distant body, and the weak sound from a near one, then we fall into an error of hearing. Generally, we are easily deceived in judging of the distance from which sound proceeds; here, too, vision and reason materially assist our judgment.

The different degrees of convergence or divergence in the sonorous rays do not appear to influence hearing, nor do we modify the direction of the sonorous rays, but to make a greater number enter into the ear. This is the effect produced by hearing trumpets which are used by the deaf. It is sometimes necessary to diminish the intensity of sounds; in this case we place a soft inelastic substance in the meatus auditorius externus.

Pathological Tendencies.

[Though there is a striking analogy in the manner in which *sensation* and the *senses* are executed, yet that they are not identical. Violence inflicted on the sentient extremities of the nerves of sensation causes an exaggeration of their normal action, which is *pain*. But this effect is not necessarily produced in the optic nerve on wounding the retina, and the remark holds equally good with respect to the auditory nerve.

The apparatus of hearing is simple, very securely placed, and much less prone to disease than that of vision. Its morbid conditions, however, are much less within the control of art. Little has been accomplished by modern science in this respect. The *cerumen* sometimes becomes inspissated, and accumulated in such quantity as to close up the external opening, and cause deafness. Perhaps the most common disorder of this apparatus is obstruction of the eustachian tube. Catarrhal affections, which are so common in all climates and classes of persons, are generally attended with more or less inflammation of the posterior fauces. The inflammation is apt to extend up the lining of the eustachian tube, and from the consequent tumefaction or morbid secretions the tube becomes obstructed, and the air confined in the cavity of the tympanum. Thus the free oscillatory movements of the tympanum are impeded, and deafness produced. On closing the nose and mouth, and making a forcible expiration, while the eustachian tube is clear, the air is felt to impinge upon the *membrana tympani.*

We are thus enabled to determine with considerable certainty when the deafness arises from obstruction of this tube. There are two remedies which have been much practised in modern times for deafness arising from this cause, founded on the physiological facts referred to. The one consists in puncturing the membrana tympani; the other, and more modern operation, proposed by M. Deleau, of Paris, in dilating the obstructed eustachian tube by injecting into it air, warm water, and other bland fluids. Inflammation of the lining membrane of the external ear is a common and painful disorder, especially in childhood, often coming on periodically. It frequently commences with exquisite pain and intolerance of sound; in a short time a purulent discharge occurs, accompanied with relief to the pain, and as the discharge gradually subsides the health is restored. In some cases the inflammation puts on a chronic form, and is attended with thickening of the membrana tympani; in others, there is ulceration of the membrane and destruction of the small bones, which are discharged through the external ear; in both cases, deafness is produced. Not unfrequently the purulent discharge from the external ear, the common termination of inflammation of the lining membrane, suddenly ceases, and is followed by return of the pain and great sensibility to sound. In these cases of relapse, the inflammation is very apt to extend through the bony structure to the textures of the brain. This organ also necessarily sympathizes in all the changes which occur in the encephalon. In some cerebral affections, its susceptibilities are so exalted as to be painfully affected with the weakest sound; in others, so depressed as to be insensible to the loudest. The state of its functions thus constitutes one of the best guides in many acute diseases for determining the pathological condition of the brain. In acute inflammation great morbid sensibility to sounds and tinnitus aurium are common symptoms; while tumours of the brain, effusions of serum or blood, are indicated by deafness in one or both ears. There is, however, but little sympathy between the ears and the other important organs.]

Modification of Hearing by Age.

The ear is formed very early in the fœtus. At birth, the internal ear and small bones are nearly the same as at any period of life, but the parts which belong to the middle and external ear are not in a condition to act, which constitutes an essential difference between the eye and ear. The external cartilage is comparatively very small and soft, of course possesses but little elasticity, and is, therefore, but imperfectly prepared to perform the function to which it is destined. The parietes of the external passage are in a similar state; the membrana tympani is very oblique, forming, in some measure, the upper part of the canal, and is therefore badly arranged to receive the sonorous rays. All the external part of the ear is covered with a soft whitish matter, which obstructs its functions. The cavity of the tympanum is also proportionally small, and, instead of air, contains a thick mu-

cus. The mastoid cells do not exist. But, as age advances, the auditory apparatus acquires that arrangement and perfection which we have described in the adult. In old age, the changes that take place in the physical structure of the ear are so far from being unfavourable, as happens in the eye, that they appear, on the contrary, to improve it. All the parts become harder and mory elastic; the mastoid cells extend themselves through the *os petrosum*, and surround, on all sides, the cavities of the internal ear.

The loudest noises have no sensible effect upon newborn infants, but, after some time, they seem to distinguish sharp sounds; these are the sort of sounds generally made use of by nurses to attract their attention. It is a long time before an infant judges correctly of the intensity or direction of sounds, and especially before he attaches any meaning to articulate sounds. As he prefers the most vivid light, so in the same manner he is pleased, for a long time, with sounds that are loud and sharp. But, although the physical structure of the auditory apparatus becomes more perfect in old age, it is, nevertheless, certain, that the hearing becomes more imperfect, even at its first approach, and that there are very few old men who are not more or less deaf. This appears to arise from a diminution of the humour of Cotunnus, and a progressive loss of sensibility in the auditory nerve.

CHAPTER V.

SENSE OF SMELL.

There are many bodies in nature which suffer particles of extreme tenuity to escape from them, which diffuse themselves in the atmosphere, and are carried, by this vehicle, to a great distance. These particles constitute *odours*. One of the senses is destined to recognise and appreciate these particles, and thus an important relation is established between animals and them. Those bodies, the particles of which are fixed, are called *inodorous*.

There is a great difference among odorous bodies in the manner in which they develop their odours. Some do not suffer them to escape, except when they are heated, others when they are rubbed; some exhale weak odours, others only those which are strong. Such is the tenuity of these odorous particles, that a body may exhale them for a long time without altering, sensibly, its weight.

Every odorous body has a peculiar odour. As these bodies are very numerous, it has been attempted to classify them, but all these attempts have heretofore proved fruitless. We can only distinguish odours into weak and strong, agreeable and disagree-

able. We speak, however, of a musklike odour, aromatic, and fetid odours, &c. They are likewise sometimes distinguished into fugitive and tenacious. For the most part, however, we can only designate them by comparing them with that of some known body.

Nutritious, medicinal, and even poisonous qualities have been attributed to odours ; but, in such cases, these opinions seem to have been formed by confounding the influence of odours with the effects of absorption. A man who pounds jalap for some time will be purged, as if he had taken its substance into his stomach. This effect cannot be properly referred to the effect of odour, but to the fine particles of the jalap which are floating in the air, and which are thus introduced into the circulation, either with the saliva, or the air which he respires. It is to the same cause to which we must attribute the intoxication of persons exposed for some time to the fumes of spirituous liquors. The air is the vehicle by which odours are generally transported to a distance, but they are also produced in a vacuum. There are some bodies which dart forth their odoriferous particles with a considerable degree of force ; but this subject has not received the attention which it deserves. It has not been fully ascertained if odours observe, in their progress, anything analogous to the convergence and divergence, reflection and refraction of luminous rays. Odours attach themselves to, or combine with, many fluids, as well as many solid bodies ; a method which is often taken to preserve them for a long time. Liquids, vapours, gases, and many solid bodies, when reduced to an impalpable, or even coarse powder, have likewise the property of acting upon the organs of smell.

Apparatus of Smell.

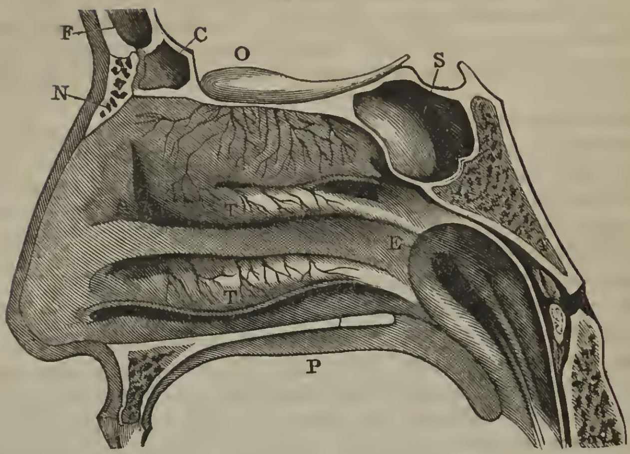
The olfactory apparatus may be compared to a sort of sieve, placed in a spot over which the current of air that is introduced into the chest in respiration passes, and which is destined to detain all the foreign bodies which may happen to be mixed with the air, particularly odours.

This apparatus is extremely simple. It differs essentially from that of vision or hearing in this, that we do not find before the nerve any parts which are placed there to modify the physical effects of the excitant, the nerve being, in a great measure, naked. The apparatus is composed of the pituitary membrane which covers the nasal cavities, of the membrane which lines the sinuses, and of the olfactory nerve and different filaments of the nerve of the fifth pair.

[The following is a vertical and longitudinal section of the human nostril.

The olfactory nerve is seen passing through the cribriform plate of the ethmoid bone at O, to be distributed to the pituitary membrane which covers the nasal passages and cells. Several of these cells are seen, as the sphenoidal sinus S, the frontal sinus F, and one of the ethmoidal cells C. N is the nasal bone; P the

(Fig. 16.)



palate; E the mouth of the eustachian tube; **T T** the cornets, or turbinated bones.]

The Pituitary Membrane.—This covers the whole extent of the nasal fossæ, increases very much the thickness of its cornets, and is prolonged beyond their edges and extremities in such a manner that the air cannot traverse the nasal fossæ, except by very narrow and lengthened passages. This membrane is thick, and adheres tenaciously to the bones and cartilages to which it is attached. Its surface presents an infinite number of small projections, which are considered by some as nervous papillæ, but have been supposed by others to be mucous cryptæ; they are, however, very vascular. These projections give to the membrane a velvetlike appearance. The pituitary membrane is smooth and soft to the touch, and receives a great number of bloodvessels and nerves.

The passages which the air passes through to arrive at the back part of the mouth deserve attention. They are three in number, and are divided by anatomists into inferior, middle, and superior passages. The inferior is by far the largest, longest, and least oblique and tortuous; the middle is narrower, nearly as long, and deeper from above, downward; the superior is much the shortest, and most oblique, and narrowest. It is also proper to add to these passages, the very narrow interval which separates the septum of the nostrils, through its whole extent, from the external walls. Such is the extreme narrowness of all these canals, that the least swelling of the pituitary membrane renders the passage of the air through the nasal fossæ difficult, and sometimes impossible. The two superior canals communicate with cavities, which are considerably spacious, hollowed out of the bones of the head, and are called sinuses. They are the maxillary, palatine, frontal, and sphenoidal sinuses. Those which are found in the thick part of the ethmoid bone are sometimes distinguished by the name of *cellulæ ethmoidales.*

These sinuses do not communicate with any others than the two superior canals. The frontal and maxillary sinuses, and the anterior cells of the ethmoid bone, open into the middle passage; the sphenoidal and palatine sinuses, and the posterior cells of the ethmoid bone, open into the superior canal. These sinuses are covered with a thin, soft, and apparently mucous membrane, loosely attached to their walls: it secretes, in greater or less abundance, a substance called nasal mucus, which is continually spread over the surface of the pituitary membrane, and appears to be useful in smelling. A considerable extent of these sinuses is always found where this sense exists in great perfection. This is, at least, one of the most positive results of comparative physiology.

The Olfactory Nerve.—This arises by three distinct roots from the posterior, inferior, and internal part of the anterior lobe of the brain. In passing towards the cribriform plate of the ethmoid bone, it is of a triangular shape; here it becomes suddenly enlarged, and is then divided into a great number of small filaments, which are ramified over the pituitary membrane, principally at the superior part of this membrane. Like the nerves of vision and hearing, the olfactory is insensible to compression, pricking, &c., and even the contact of bodies the odour of which is strong.

It is important to remark, that the filaments of the olfactory nerve have never been traced on the inferior cornet, or spongy bone, on the internal face of the middle, nor any of the sinuses. The pituitary membrane not only receives the nerves of the first pair, but receives also a great number of filaments arising from the internal face of the spheno-palatine ganglion; these filaments are distributed over the inferior parts of the membrane. It is supplied also by the ethmoidal filament of the nasal nerve, and receives from it a large number of small filaments. The membrane which covers the sinuses receives also some small nervous branches.

The nasal fossæ communicate externally through the nostrils, the form, magnitude, and direction of which vary in different individuals. The interior of the anterior nares is garnished with hairs, and their dimensions are increased and diminished by the action of certain muscles. The nasal fossæ open into the pharynx by the posterior nares.

Mechanism of Smell.

The apparatus of smell presents some striking differences from those of vision and hearing. In the latter, the general sensibility is distinct, as regards its seat, from the special sensibility. Thus, the conjunctiva presents the one and the retina the other. In the ear, the meatus auditorius externus exercises the first, and the auditory nerve the second. If the two properties exist in the pituitary, they are much more difficult to distinguish. It appears, however, that these two properties are sometimes isolated. Some individuals are destitute of the sense of smell, though the pituitary

membrane is exceedingly sensitive to the contact of foreign bodies, so as to be able to distinguish their physical properties, as, for example, different kinds of tobacco.

Experiment has demonstrated to me that the general sensibility of the pituitary membrane ceases on the section of the fifth pair of nerves. As soon as the division is made, contact, pricking, or the application of corrosive agents, cease to produce any effect upon the sensibility of the membrane. In this respect, then, it resembles the conjunctiva. But, what is equally remarkable, is the entire loss of sensibility to the most penetrating and pungent odours, as ammonia, the acetic acid, &c. It thus appears that the olfactory nerve in this respect resembles the optic and auditory nerves: it can only act while the integrity of the fifth pair is preserved. The following fact differs still more from the commonly-received opinions respecting the functions of the first pair of nerves.

I destroyed these two nerves in a dog; I then presented to the animal strong odours. He perfectly perceived them, and acted as under ordinary circumstances. I endeavoured to ascertain the same thing with respect to weak odours, as the aliments; but I could not arrive at results sufficiently positive to affirm that these odours acted upon the nose of the animal. It would thus seem possible that the olfactory nerve is not the true nerve of smell, and that the sensibility to odours is confounded with the general sensibility in the same nerve. (See *Jour. de Physiologie*, tome iv.) Many pathological facts, which would have passed unnoticed before the publication of these experiments, have since confirmed these results. Cases of individuals have been observed in whom the olfactory nerves were completely destroyed, have preserved the sense of smell, taken snuff with pleasure, and distinguished its different qualities; complaining also, like others, when exposed to disagreeable odours.* On the other hand, in cases where the fifth pair of nerves were destroyed, although the olfactory remained unchanged, the individual had lost not only the sense of smell, but also the sensibility of the pituitary membrane. May we not say that these authenticated cases, collected in the public hospitals of the capital, are the exact repetition of my experiments? and do they not render the results still more probable?

The sense of smell is exerted at the moment that the air traverses the nasal fossæ in its passage to the lungs. It is very rare that we can perceive any odour in the air at the moment it escapes from these organs, though this is sometimes observed, especially in certain organic affections of the lungs.

The mechanism of smell is extremely simple: it is only necessary that the odoriferous particles should be stopped by the pituitary membrane, especially in those narrow passages where it receives the filaments of the olfactory nerve. As it is precisely at the superior part of the nasal fossæ, where the passages are the

* See *Jour de Physiologie*, tome v., case of M. Berard, communicated by M. Beclard.

narrowest, that they are the most covered with mucus, it is probable that this is also a spot where a great portion of the odoriferous particles are stopped. It is easy to understand the use of this mucus; its physical properties appear to be such, that it has a much greater affinity for the odoriferous particles than for the air. It therefore separates them from this fluid, and retains them upon the pituitary membrane, where they produce the sense of smell. It is very important, in the exercise of this function, that the nasal mucus should preserve the same physical properties: every time they are changed, as happens in the different stages of coryza, the sense of smell is either lost or essentially impaired.*

From what has been said of the distribution of the olfactory nerves, and the branches of the fifth pair, it is evident that odours, when they come to the superior part of the nasal cavities, will be more easily and vividly perceived. It is for this purpose that we modify inspiration, so that the air shall be directed upon this point, when we wish to perceive vividly or accurately the odour of a body. It is for the same reason that those who take snuff endeavour to place this substance towards the upper part of the nasal fossæ. It would seem that the internal surfaces of the cornets are extremely well arranged to stop the odour at the moment that the air passes through; and, as their sensibility is very great, we are induced to believe that they assist in the function of smelling, although the filaments of the first and fifth pairs of nerves have never been traced upon them.

Physiologists are not agreed as to the precise use of the nose in smelling; it appears intended to direct the air charged with the odorous particles towards the superior part of the nasal fossæ. Persons whose noses are deformed, especially flattened, and those who have small nostrils, directed forward, have, generally, the sense of smell very imperfect. The loss of the nose, by disease or by accident, causes nearly an entire loss of this sense. According to the interesting remarks of M. Beclard, we may restore the use of this sense, in individuals who are in this situation, by fitting an artificial nose.

It has been supposed that the use of the sinuses, for the most part, consists in supplying the nasal mucus. But there are other uses which may be attributed to them, viz., to serve as a depôt of the air charged with the odorous effluvia, and to increase the surface to which it may be applied. But all these opinions must be considered doubtful. It is certain, at least, that these cavities are not well fitted to receive the impression of odours. Diseases have proved this in man, and direct experiments on animals give the same result. Vapours and gases appear to act in the manner of odours on the pituitary membrane; the mode, however, is

* This is the explanation given in the School of Medicine in Paris. It seems at first satisfactory, but, on a nearer examination, it will be found to rest on many assumed facts, *e. g.*, the affinity of the nasal mucus for odours, the deposition of the odorous particles on the pituitary membrane, &c.

probably somewhat different. Bodies reduced to a coarse powder have also a powerful action on this membrane; their first contact is even painful; but habit changes this pain into pleasure, as we see in snuff-takers. In the practice of medicine, we have often recourse to this property of the pituitary membrane, of producing instantaneously an acute pain by the application of certain pungent odours.

In speaking of the sense of smell, it is not proper to be silent concerning the hairs which garnish the nostrils: they are, probably, intended to prevent the foreign bodies which float in the air from entering the nasal fossæ. Their functions are very analogous to those of the eyelashes, and of the hairs found at the entrance of the external passage of the ear.

[This sense is connected with the digestive and respiratory apparatus. The odour of spices and other condiments, and of certain aliments, not only indicates their adaptation for digestion, but sharpens the appetite, gives zest to the taste, and promotes the chymification. Smell and taste are so intimately associated, that sometimes it is difficult to separate them. Thus we say that certain articles smell and taste alike. Smell also cooperates with taste in pointing out the unsuitableness of certain articles as aliments. The instinctive perceptions, derived from these organs, vary in different animals, according to the capacities of their digestive apparatus; the odour and taste of the same substances are obviously agreeable to some, and disgusting to others. They appear to be much more certain guides in many of the inferior animals than in man. Thus the ergot, though poisonous to man, as well as other animals, when mixed with farinaceous substances, does not impart a disagreeable taste or odour to us, while many of the inferior animals will rather die of hunger than taste it. In some animals, smell is the predominant sense, its extent of action surpassing that of the eye or the ear in assisting it in escaping from its enemies or seeking its prey. The carnivorous birds have been particularly remarked for the great distance from which they can discover their prey, which has been attributed to this sense, although at present some doubt exists on this subject. But its offices in some instances are altogether disconnected with digestion, many odours being agreeable or disagreeable without exciting ideas associated with that function. It thus sometimes acts as a sentinel in guarding the organization against those agents which, by their direct action on the lungs, or in other ways, might prove injurious. The near proximity of this organ to the encephalon seems to exert an influence on its functions. Thus certain odours almost immediately cause headache, vertigo, and syncope; even asphyxia has been thus produced. In some animals, in which the sense of smell is very acute, a direct communication exists between the nasal passages and the lateral ventricles of the brain.

The intimate connexion existing between the organ of smell

and the encephalon is also shown by the effects of pungent odours in syncope. The loss of consciousness and power of deglutition often renders this the only point at which the sinking excitability of the system can be effectively approached and roused into action by the use of stimuli. The extreme disgust which certain odours inspire, as animal and vegetable substances in a state of decomposition, &c., is a salutary instinct guarding us against influences deleterious to the organization. Like the other superadded endowments of man and the higher orders of animals, it is also often used as a mere luxury—a source of agreeable sensations, independently of absolute utility in the organization. It is quite obvious that the various details in the arrangement of the nasal passages and cavities are designed to present a large surface for the expansion of this membrane, and facilitate the contact of the air with it. Thus the greater their expansion, generally the more acute the sense of smell; the form of the head in the greyhound and pointer, and their habits, illustrate this.

It would seem that the direction and force with which the odorous particles strike against the membrane are important circumstances in the exercise of this sense. At any rate, when the passage of the air is obstructed by the inflammation of the membrane, or the nose removed, this sense is impaired or lost. This sense, though frequently impaired or lost by disease, is perhaps less liable to false impressions or illusions than either of the others. A false sensation, however, is often produced in this part by catarrhal inflammation. The membrane covering the narrow passages becoming swollen at certain points, impinges upon itself, which causes a sensation as if mucus were accumulated in these passages. The individual is thus prompted constantly to blow his nose, which increases the irritation.

When certain pungent and odorous substances are brought in contact with this membrane, they cause an excitation of the part, in consequence of which sneezing takes place. This commences with a sense of titillation in some part of the lining membrane of the nose; then the individual makes a deep inspiration, and this is followed by a sudden convulsive expiration, during which the air is driven with great force through the narrow nasal passages, expelling the mucus and any foreign substances that may have lodged there. Two or three of these convulsive efforts generally follow each other in rapid succession. In the normal state of this membrane, this is an instinctive effort to remove some local irritant, and does not frequently occur; but in some morbid conditions, such is its irritability, that the sneezing is excited by the slightest cause, and is almost incessant. In catarrhal inflammation this is generally one of the earliest symptoms, and is usually accompanied with a copious but thin secretion. This also sometimes constitutes a prominent and distressing symptom in slight paralytic affections. In a case of partial hemi-plegia of the right side, in which the vision and audition were affected slightly, the sneez-

ing, attended with a copious discharge from the right nostril, is incessant and most distressing. In a more complete paralysis the reverse of this exists. Sternutation, excited by a class of agents called *errbines*, was formerly often had recourse to in various affections of the head. It is, perhaps, too seldom employed in the modern practice of medicine.]

Modification of Smell by Age.

The olfactory apparatus is but imperfectly developed at birth. The nasal cavities and the different cornets scarcely exist, and the frontal sinuses cannot be distinguished, though there is reason to think that infants are capable of exercising this function. I think I have seen children, soon after birth, exert this sense upon the aliments which were presented to them. With the progress of age the nasal cavities develop themselves, the sinuses become formed, and, in this respect, the olfactory apparatus continues to grow more perfect until old age. The sense of smell remains until the last moments of life, excepting in those cases where there is some organic affection of the part, such, for example, as some change in the secretion of the mucus, &c., which frequently takes place.

CHAPTER VI.

THE SENSE OF TASTE.

Taste is the impression made upon the tongue by certain bodies; those substances which produce this effect are called *sapid.* It has been supposed that the degree of sapidity in any body might be judged of by its solubility. But there are some bodies which are insoluble, yet have a strong taste, and there are others which are very soluble that have scarcely any perceptible taste. Sapidity appears to have some relation to the chemical nature of bodies, and to the general effects which they produce on the animal economy.

Tastes are very various and numerous; several attempts have been made to divide them into classes, but this has never yet been done with complete success; at the same time, we have been rather more fortunate, in this respect, than with odours. This undoubtedly arises from the fact, that the impressions which we derive from the sense of taste are less transient than those of smell. The propriety of the following distinctions among sapid bodies is universally acknowledged, viz., *acrid, acid, bitter, sweet, rough,* &c. There is another division of these bodies which will be admitted by every one, because it is founded upon organization; it is that

of *agreeable* and *disagreeable.* Animals instinctively establish this distinction. This division is also the more important, because those bodies the taste of which is agreeable are usually those that are most nutritious; and, on the contrary, those the taste of which is disagreeable, are often injurious.

Apparatus of Taste.

The tongue is the principal organ of taste; at the same time, the lips, the internal surface of the cheeks, the palate, the teeth, the pharynx, the œsophagus, and the stomach itself, are susceptible of impressions from the contact of sapid bodies. The salivary glands, the excretory ducts of which open into the mouth, and those follicles which pour out mucus into this cavity, concur powerfully in the function of taste. Independently of the mucous follicles found on the superior surface of the tongue, which have received the name of *fungous papillæ*, there are still smaller projections, the most numerous of which are called *villous papillæ;* and still others, less numerous, which are disposed on the side of the tongue in two ranges, and are called *conical papillæ.*

All the nerves distributed on those parts which are destined to receive the impression of sapid bodies must be comprised in the *apparatus of taste.* Thus the inferior maxillary, and many branches of the superior maxillary nerves, among which it is proper to mention the filaments which arise from the *spheno-palatine ganglion*, particularly the *naso-palatine nerve* of Scarpa, the nerve of the ninth pair, the glosso-pharyngeal nerve, &c., all appear to assist in the function of taste.

The lingual nerve of the fifth pair is usually considered by anatomists as the principal nerve of taste; for its filaments, they assert, may be traced to the villous and conical papillæ of the tongue. I have myself attempted to do this, but in vain. Notwithstanding I have employed the most delicate instruments, magnifying glasses, and microscopes completed according to the principles of Mr. Woolaston, all my efforts have been unsuccessful. We entirely lose sight of them the moment we arrive at the exterior membrane of the tongue. We do not succeed better with the other nerves which are distributed over this organ.

Mechanism of Taste.

In order that we may exercise the function of taste perfectly, it is necessary that the mucous membrane which covers these organs should be in a state of integrity, that it should be covered with mucus, and that the saliva should be poured out abundantly. When this membrane is dry, the taste is very imperfect. It is likewise necessary that these fluids should be in a natural state, for if the mucus be thick and yellowish, or if the saliva be acid or bitter, &c., the taste will be defective.

Some authors assert that the papillæ of the tongue are in a complete state of erection during the action of tasting; I believe, however, that this assertion is entirely destitute of foundation.

It is sufficient that the body be in contact with the organs of taste, in order that we may judge correctly respecting it; but, if it be a solid body, it will be often necessary that it should be first dissolved in the saliva, but this is not necessary in liquid or gaseous bodies.

It would seem that sapid bodies produce a certain chemical action upon the epidermis of the mucous membrane of the mouth; this is at least the case in some instances; *e. g.*, vinegar, mineral acids, alkalis, a great number of salts, &c. In these cases, the colour becomes changed; sometimes it becomes white, sometimes yellow, &c. They produce analogous effects upon the dead body. It is probable that the manner in which this combination takes place has some relation to the promptitude with which sapid bodies act, and the duration of the impression.

No satisfactory explanation has yet been given why the teeth are strongly influenced by certain sapid bodies. It appears from the researches of M. Miel,* a distinguished dentist of Paris, that this is the effect of imbibition. The experiments of this gentleman prove that the teeth imbibe promptly the fluids with which they are in contact. This extends even to the central part of the tooth, where the nerve is placed, which is a branch of the fifth; hence the sapid impression.

The different parts of the mouth appear to have each a peculiar susceptibility to the action of sapid bodies; for some more particularly affect the tongue, some the teeth, and others the gums. There is another class of these bodies, the action of which seems to be almost exclusively confined to the palate and pharynx.

We are indebted to Messrs. Guyot and Admyrault for the following new and curious experiments:

Experiment 1st. The anterior part of the tongue being placed in a sack of very flexible parchment, a small quantity of conserve or very sapid jelly was placed between the lips. This was moved about pressed by the lips, but no other impression was experienced than what arose from consistence and temperature. The same result was observed when the sapid substance was placed on the anterior part of the inner surface of the cheek, and of the arch of the palate, provided that neither the substance itself, nor the saliva impregnated with it, came in contact with the tongue. This result was verified with diluted hydrochloric acid and water sweetened with sugar. It was impossible to distinguish one of these substances from the other, no taste being perceptible from either.

Experiment 2d. If we separate the cheek from the alveolar arch, and cover it interiorly with a little acid ice, or sweetened ice, no taste is perceptible, provided we take the precautions respecting the tongue and saliva above indicated. This experiment may be varied by placing between the cheek and the alveolar arches a soluble body like sugar or common salt, or a little ex-

* This gentleman was not only distinguished by his learning, but his patriotism and courage. He fell in the glorious struggle of July, 1830.

tract of aloes. The taste is not manifest until it deliquesces, but if we permit the saliva to spread itself to the edges of the tongue, the taste becomes very vivid.

Experiment 3d. The tongue was covered as in the first experiment, but to a greater extent, by means of a prolongation of the parchment, which extended almost to the epiglottis. A number of pulpy substances with strongly-marked taste were swallowed, care being taken during the deglutition to place them successively in contact with all parts of the palatine arch and of the veil of the palate; it was observed that the sense of taste was only manifest when these substances came in contact with this last part.

Experiment 4th. If the whole extent of the palatine arch be covered with a sheet of parchment, and a sapid body placed upon the tongue and swallowed, the impression thus produced is not less vivid.

Experiment 5th. A fragment of the extract of aloes attached to the extremity of a stylet, and rubbed over all the parts of the palatine arch and the veil of the palate, gives the following results. Through the whole extent of the palatine arch, from the edges to the centre, there is no other impression than that of feeling. It is the same precisely with the uvula, the pillars of the veil of the palate, and the greater part of that organ. But at the anterior, middle, and superior part of that organ, a line below its point of insertion into the palatine arch, there is a small surface, without precise limits, not descending to the base of the uvula, but about three quarters of a line distant from it, prolonging itself, and losing itself insensibly at the sides; this surface perceives tastes in a remarkable manner. The same instrument carried into the back part of the mouth, and applied to the posterior surface of the veil of the palate and the mucous membrane of the pharynx, demonstrates that these parts do not participate in the sense of taste. If, then, we except the part we have indicated of the veil of the palate, the tongue is the exclusive seat of taste; but all parts of the mouth concur in this sense.

Experiment 6th. If the tongue be covered with a piece of parchment, pierced at its centre in such a way as to correspond to the middle of its dorsal face, if we apply to this part an acidulated or sweetened conserve, there is no sensation of taste, even though pressed against the palative arch. The taste is only manifest when the saliva impregnated with it reaches the edges of the tongue. If we repeat this experiment over the greater part of the dorsal surface of the tongue, the result will be found the same.

Experiment 7th. A sapid body placed before the frenum of the tongue, and compressed by the inferior surface of the organ, does not produce the sensation of taste.

Experiment 8th. A piece of aloes, or a sponge soaked with vinegar, and carried to the different parts of the tongue, gives the following results. The whole dorsal face of the tongue does not possess the property of taste, but it is manifested as we approach

the circumference, in an extent from one to two lines on its edges, and from three to four from the apex.

Taste is perceived vividly and nearly uniformly on the edges of the tongue, to within about four lines of their anterior extremity. From this point it becomes stronger to the apex, where it exists at its maximum intensity.

There are some bodies which leave for a long time their taste in the mouth; this is especially the case with aromatic substances. This *remaining taste* is sometimes perceived over all the mouth, and sometimes occupies only one spot. Acrid bodies, for example, leave their impression in the pharynx, acids on the lips and teeth; peppermint leaves an impression which exists at the same time in the mouth and pharynx.

It is necessary that bodies should remain for some time in the mouth, in order that their taste may be appreciated. When they pass rapidly through this cavity, the impression which they make is almost nothing; this is the reason why we swallow quickly those substances the taste of which is disagreeable, and why, on the contrary, we allow those things to remain long in the mouth the taste of which is pleasant.

When we take a substance, the flavour of which is strong and permanent, vinegar for example, we become insensible to the action of less pungent bodies. We often make use of this observation to enable our patients to avoid the disagreeable taste of certain medicines.

We are capable of perceiving many tastes at the same time, and of distinguishing their different degrees of intensity.

Thus, we are sometimes enabled to distinguish, very exactly, the chemical nature of different substances, as we see in chemists, epicures, and persons who make a business of tasting wines and other liquors. By these means we can sometimes form a very exact judgment of the chemical nature of bodies. The taste, however, never arrives at this degree of perfection but by long experience, or, rather, by a complete education.

It may be inquired if the lingual nerve be the essential nerve of taste? This question, formerly so obscure, no longer presents any difficulty: physiological experiments and pathology have completely resolved it.

If the lingual nerve in an animal be divided, the tongue continues to move, but it loses the faculty of taste. In this case the palate, the gums, and the internal surface of the cheeks preserve their sensibility; but if the trunk of the fifth pair be divided in the cranium, the perception of taste is completely lost, even as respects the most acrid and caustic substances. This total abolition of taste has been noticed in persons in whom the trunk of the fifth pair is compressed or altered. Everything I eat, says a patient in this state, seems to me like earth. In the sense of taste the general sensibility is confounded with the special. It is also worthy of being remembered, that the two phenomena pertain evidently to the same nerve.

[There must be certain inherent qualities in the substances presented to the tongue, called *sapid*, in order to produce the sense of taste. These qualities differ very much, both in degree and kind, in different substances. This sense is placed as a sentinel over the digestive apparatus, and indicates, with considerable certainty, those substances which are unsuitable for the action of these organs. But the tongue does not only possess the power of ascertaining the sapidity of bodies; it has also, in a very high degree, the sense of touch and the power of voluntary motion, and, as we have already seen, is intimately associated with the organ of smell. The approach to the important series of organs appropriated to digestion is thus directly guarded by three of the senses, taste, touch, and smell, assisted by vision and the power of voluntary motion. We judge of the fitness of any substance for food not only from its appearance, odour, and taste, but from its degree of consistency and size, by the sensation and voluntary motion of the tongue, before we introduce it into the stomach by deglutition.

The tongue is not to be regarded as exclusively an organ of sense, but also as a part of the digestive apparatus. On the reception of food into the mouth possessing agreeable sapid qualities, if the individual be in health, the digestive apparatus is roused into action. The excitement of these organs is dependant not only upon the agreeableness, but the pungency of the food. If it be piquant, the appetite becomes urgent; if insipid, the reverse. The agreeableness of the taste diminishes with the repletion of the stomach; it gradually becomes insipid, and at last disgusting. The sense of smell also conspires, with that of taste, in quickening the action of the digestive apparatus. It is almost impossible to separate the action of these two senses. Those articles which are insipid are also inodorous, and *vice versa*. If we close the nostrils, the sense of taste is exceedingly weakened. This is often done in taking nauseous draughts, it being generally supposed that we thus merely avoid the disagreeable odour; but careful observation shows that the offensive taste is also diminished. The intimate association of these organs with the digestive apparatus is shown by the influence produced upon their functions by its disordered state. Under these circumstances, the organs of taste and smell become indifferent, or even offended, by those very aliments that were before the most agreeable. Even the appearance of the tongue varies with the state of the stomach, so that we can, with considerable certainty, determine the state of the latter by inspection of the former. The accuracy of this guide has, no doubt, been exaggerated, especially by the Broussaisan school. Still, it is, unquestionably, a most useful index in the greater number of diseases. A consideration of these appearances will be found more satisfactory in connexion with the pathological conditions of the digestive apparatus.

With respect to the action of the senses, it may be remarked, that the certainty with which they indicate the qualities of bodies

varies very much in different individuals, and in the same individual at different times. In the normal state of these organs, the impressions they are destined to receive are slight and imperfect, unless the attention is directed to the subject. The individual is often scarcely conscious of the numerous slighter impulses to which they are subjected. It is only when these impressions are unaccustomed, or stronger than usual, or excite certain associations, or when the individual desires to ascertain certain phenomena, that the action of the organs is sufficiently roused to produce their full effect. When diseased, their susceptibility is either impaired or lost, or morbidly exalted, so that the slightest impression becomes disagreeable, or painful and inaccurate. In forming our judgment respecting the qualities of bodies, where we are doubtful, we seldom rely exclusively upon one of the senses, but compare the impressions made upon each. If, *e. g.*, it be concerning the suitableness of an aliment, we subject it to the action of all the senses; except, perhaps, of hearing, before we venture to introduce it into the stomach. Like the other organs, the senses improve as we approach maturity, and become more acute and discriminating by suitable training and use. A landsman, on first going to sea, is astonished at the promptitude with which sailors discover a distant sail, and the accuracy of their judgment as to the character of the stranger, and the course she is steering, while it appears to him, perhaps, an obscure speck in the horizon. Those varieties of the human species which possess dark complexions have been thought to exhibit greater acuteness of the senses than the European. This opinion is, probably, founded on the habits of all wandering and barbarous tribes who live by the chase and war, which necessarily lead to the constant exercise of the senses, as on them their safety, and even existence depend. It is astonishing to what a degree of perfection they attain. The North American savage will pass through forests he had never seen, in a given direction, or follow the trail of his enemies for days, guided by marks imperceptible and unappreciable to the senses of civilized man. Pallas, who was familiar with the habits of the wandering tribes of Asia, remarks of the Calmucks, "They have a fine nose, a good ear, and an extremely acute eye. On their journeys and military expeditions they often smell out a fire, and thus procure quarters or booty. They can distinguish, by smelling at the hole of a fox or other animal, whether it be there or not. By lying flat, and putting their ear to the ground, they can catch, at a great distance, the noise of horses, a flock, or a single animal that has strayed. But nothing is so surprising as the perfection of their eyes, and the extraordinary distance at which they often perceive, from inconsiderable heights, small objects, as the rising of dust, caused by cattle or horsemen, notwithstanding the undulation of their boundless steppes, and the vapours that constantly float over them. In the expedition of the Cham Ubraschi against the Kubanians, the Calmuck force would certainly have missed the enemy if a common Calmuck had not perceived, at the distance of

thirty versts, the smoke and dust of the hostile army, and pointed them out to other equally experienced eyes, though the commander could discern nothing, even with a good glass."

The loss of one sense is in some degree compensated by the improvement of those that remain. A remarkable example of this occurs in the case of Julia Brace, an inmate of the Hartford Deaf and Dumb Asylum, who is deaf, dumb, and blind. Such is the acuteness of her sense of smell, that she is enabled to select her own clothes from among those of upward of a hundred persons, after they have been washed, and is in the habit of doing so without the slightest mistake. It is evident that she is guided almost exclusively by the smell.]

Modification of Taste by Age.

It is difficult to say if taste exists in the fœtus; it is certain, however, that the principal organ, and the nerves which are sent to it, are fully developed. That this sense exists at the time of birth there can be no doubt, as any person may satisfy himself by rubbing upon the tongue, or even upon the lips, any bitter or sweet substance. The impressions of taste appear to be very vivid in children, as is shown by their repugnance to everything the flavour of which is strong.

Taste remains in the most advanced age, though it is true that it becomes weaker, and that old persons, generally, prefer aliments and drinks the flavour of which is strong. But this is one of the peculiarities of their organization, which requires very active excitants for the maintenance of its powers when they have become very weak.

Taste assists us in the choice of aliments; together with smell, it enables us to distinguish those substances which are injurious from those that are useful; it is likewise the sense which enables us to form the most correct judgment of the chemical composition of bodies.

CHAPTER VII.

OF TOUCH.

Touch is the sense which makes us acquainted with the greatest number of the properties of bodies. In consequence of its being less subject to error than the other senses, and because, in certain cases, it enables us to detect it, it has been considered as the most perfect of the senses. But it will be seen that its advantages have been very much overrated, both by physiologists and metaphysicians.

Though essentially the same, we may distinguish between *sensation* and *touch*. *Sensation* is, with few exceptions, common to every part of the body, especially the cutaneous and mucous surfaces; it exists in all animals, while touch is evidently confined to parts particularly destined to this purpose. Touch does not exist in all animals, but it is nothing more than sensation united with muscular contraction, and directed by the will. In a word, in the act of sensation, we may be considered as being passive, but in exercising the sense of touch, we are active.

Apparatus of Touch and Sensation.

This sense enables us to become acquainted with nearly all the physical properties of bodies. Their form, dimensions, different degrees of consistence, weight, motion, and vibration are all circumstances of which we are enabled to judge with accuracy by the sense of touch and sensation.

[Though sensation exists in almost all the structures, yet the extremities of the fingers may be considered as more particularly the seat and organ of touch. The hand being broken up into numerous joints, and being very flexible, is well suited to explore objects by this sense. The tip of the tongue also possesses this property in a very eminent degree. Though we have no means of multiplying the power of this sense, as in hearing and vision, yet it is capable of great development; in some instances it is alleged that individuals have been able to distinguish certain colours by its aid.—(*Begin.*)

Of the grosser properties of bodies, as their density, roughness, sharpness, temperature, &c., it is more direct and less liable to deception than the other senses; it depends on the integrity and continuity of the fibrous structure. This appears to be an indispensable condition. It thus constitutes a most important sentinel in protecting the organization from the various noxious influences to which it is exposed. Not only the integument, but the muscles, in many instances, receive nerves of sensation, as well as those of voluntary motion. Hence it happens, especially in the superior extremity, which may be considered the organ of touch in man, that those two properties, sensation and voluntary motion, are intimately associated. We estimate the properties of bodies not only by the sensation which they produce upon the skin, but also by the resistance they present to the muscular action. Again, the muscular action is often guided by sensation. The effort we make in raising, grasping, holding, or crushing bodies is, at least, partly determined by the impression which their resistance produces upon the sensation. Thus we occasionally meet with cases of paralysis of the nerves of sensation of different parts, while the power of voluntary motion remains unimpaired. A case is related by Dr. Yelloley of a person in whom this existed in the fore-arm. The contractile power of the muscles was perfectly natural, and so long as the patient looked at them she

had no difficulty in holding glasses, or any other common objects, but as soon as her vision was directed to any other object, the muscles, not admonished by sensation, relaxed, and allowed whatever she held in her hand to fall to the ground. This general distribution of sensation over the whole surface is indispensable to the preservation of the integument. We are thus not only admonished of injurious variations of temperature, but are also prevented from subjecting any part of this organ to a long-continued pressure, by remaining for too great a length of time in the same position. After lying for a time in the same posture, the pressure made by the prominences of the bone upon the skin becomes disagreeable, and we alter our position. We see the importance of this admonition in those cases where there is a loss of sensation in the skin from paralysis, such individuals being exceedingly subject to ulceration, and even gangrene of the integument, from this cause.]

The parts destined to this sense do not alone perform this function. In this respect it differs very essentially from the other senses. As in the great number of instances, however, it is the skin which receives the impressions of touch from those bodies which surround us, it is necessary to say something concerning its structure.

The skin forms the envelope of the body; it is lost in the mucous membranes, at the entrance of all the cavities, but it is incorrect to say that these membranes are a continuation of it.

The skin is principally formed by the *dermis*, the texture of which is fibrous, and is of different degrees of thickness, according to the parts which it covers. It adheres to these parts sometimes by cellular membrane, and sometimes by a fibrous attachment. The *dermis* is nearly always separated from the subjacent parts by a lamina, which assists in the exercise of the sense of touch.

The external surface of the dermis is covered by a solid substance secreted by the skin. called the *epidermis*. The epidermis ought not to be considered as a membrane; it is a lamina of homogeneous substance, adhering by its internal surface to the dermis. It is pierced by an infinite number of small holes, some of which allow the hairs to pass through, and others the cutaneous transpiration to escape, and, at the same time, they assist in the absorption which is carried on by the skin. These are called the *pores of the skin*. It is proper to remark, with respect to the epidermis, that it is insensible, that it does not possess any of the properties of life, and that it is not subject to putrefaction. It is constantly taken away and again replaced, and its thickness is increased or diminished according as the situation of the parts may require. It cannot be acted upon through the medium of the digestive organs.

The connexion between the dermis and epidermis is intimate; nevertheless, we cannot doubt that there is between these two

parts a particular lamina, in which important phenomena take place. The organization of this lamina is still but little known. Malpighi supposed that it was formed by a particular mucus, the existence of which has been long admitted, and which has been called the *rete mucosum*, or mucous substance of Malpighi. Others have considered it, with more reason, as a network of bloodvessels.* M. Gall compares it to the cineritious substance found in many parts of the brain.

M. Guatier, in examining with attention the external surface of the dermis, observed small reddish projections, arranged in pairs. They are easily recognised when the dermis is denuded by the action of a vesicatory. These small bodies are regularly arranged in the palm of the hand and the sole of the foot. They are sensible, and are reproduced when they have been torn away. They appear chiefly made up of bloodvessels. These bodies have been for a long time called *cutaneous papillæ*, but they have never been studied with care. The epidermis is pierced over their top by a small opening, by which we can observe drops of sweat to escape when the skin is exposed to a temperature a little elevated. The skin contains a great number of sebaceous follicles; it receives many bloodvessels, and a great number of nerves, particularly at those points which are destined to exercise the function of touch. We are entirely ignorant of the manner in which the nerves terminate in the skin; all that has been said of the nervous cutaneous papillæ is completely hypothetical.

The functions of feeling and touch are assisted by the thinness of the dermis, a temperature of the atmosphere somewhat elevated, abundant cutaneous transpiration, as well as a certain thinness and flexibility of the epidermis. When the reverse of these circumstances exist, the sensibility and the touch are always more or less imperfect.

Formerly physiologists supposed that all the nerves concur in feeling, and even touch. But this is not the case. Experiment shows, on the contrary, that many of the nerves do not possess this property, and in the same nerve that all the filaments do not present it. For example, the nerves which arise from the medulla spinalis have an anterior and posterior root. The latter alone appears to impart feeling to the organs of the trunk and extremities.

Mechanism of Sensation.

The mechanism of sensation is extremely simple; it is sufficient for the bodies to be in contact with the skin to enable us to form an idea, more or less exact, of their sensible properties. We are enabled to judge particularly of temperature by feeling. When bodies abstract caloric from us, we say they are cold, and when

* In those cases where vesicatories have been applied to the part some time before death, numerous vessels, very small, and filled with blood, may be distinguished on the external surface of the dermis.

they impart heat, we say they are warm; thus, according to the quantity of caloric of which they deprive us, or which they impart to us, we determine their different degrees of temperature. The judgment which we form of temperature is, nevertheless, far from being accurate in relation to the quantity of caloric which our bodies give off or receive; we unconsciously institute a comparison between the temperature of the surrounding atmosphere and those substances which are in contact with our bodies. If an object be colder than our body, but warmer than the atmosphere, it will appear warm to us, although it abstracts caloric when we touch it. This is the reason why such places as caves and wells, the temperature of which is uniform, appear to us cold in summer, and warm in winter. The capacity of bodies for caloric influences also our judgment of temperature; for example, how different are the sensations caused by iron and wood, at the same temperature.

A body sufficiently warm to decompose chemically our organs produces the sensation of burning. A body, the temperature of which is sufficiently low to absorb very rapidly a great proportion of the caloric of a part, produces a similar sensation; this any one may satisfy himself of by touching congealed mercury.

Those bodies which have a chemical action upon the epidermis, which dissolve it, such as the caustic alkali and concentrated acids, produce impressions peculiar to these bodies, which may serve to distinguish them.

All parts of the skin are not endued with the same degree of sensation, so that a body applied successively on different parts of the skin will cause a series of very different impressions. The mucous membranes possess a very delicate sensibility. It seems hardly necessary to point out the great sensibility of the lips, tongue, conjunctiva, pituitary membrane, and the mucous membrane of the trachea, ureters, vagina, &c., &c. The first contact of those bodies, which are not naturally destined to come in contact with these membranes, is painful, though this effect ceases by habit.

The sensation of these parts is sometimes acted upon by vapours or gases; thus, ammoniacal vapours or acids affect painfully the conjunctiva, the larynx, &c. This phenomenon is evidently analogous with smell.

Mechanism of Touch.

In man, the hand is the principal organ of touch; all the circumstances which are the most favourable to it are there found united. The epidermis is thin, polished, and very flexible, the cutaneous transpiration is abundant, and there is likewise an oily secretion. The vascular network, called the rete mucosum, is there in an unusual quantity, and the dermis is of very inconsiderable thickness; it receives many bloodvessels and nerves; it adheres to the subjacent aponeurosis by a fibrous attachment,

and is sustained by adipose substance and cellular membrane, which are very elastic. It is at the extremity, or *ball* of the finger, that all these arrangements exist in the highest degree of perfection. The motions of the hand are easy and various, so, in a word, that this part may be applied to every body, whatever may be the irregularity of its figure. While the hand remains immovable upon the surface of a body, it only performs the function of sensation; it is necessary, in exercising the sense of touch, that it should move over the surfaces of bodies, in order to make us acquainted with their form, dimensions, &c., or to compress them, so that we may form just ideas of their elasticity, density, &c. When the dimensions of a body are very great, we employ the whole hand to examine it; if, on the contrary, the body is very small, we only touch it with the extremity of our finger. This organ is much more perfect in man than in brutes; his touch is so delicate, that it has been considered as the principal source of his intelligence.

Caloric sometimes plays the same part in the sense of touch as light in vision. It makes us acquainted with the presence and certain properties of bodies, though they may be at a distance from us; and, as happens with vision, we instinctively refer to distance the impression thus arising.

From the highest antiquity, this sense has been considered more perfect than the rest, and has been described as the cause of human reason. This idea is maintained at the present day, and has even been very much extended in the writings of Condillac, Buffon, and modern physiologists. Buffon, in particular, has attached such a degree of importance to touch, that he seems to have thought that the different degrees in which this sense was cultivated was the principal cause of the difference observed in the minds of men; he enjoins, therefore, the importance of allowing infants the free use of their hands.*

The touch, however, has really no superiority over the other senses; and if, in some cases, it assists us in seeing or hearing, in others these senses afford it equal assistance; nor is there any reason to believe that the ideas which it excites in the brain are more vivid than those which arise from the action of the other senses.

Modifications of Sensation and Touch by Age.

It is probable that the fœtus does not exercise this sense, at least in its more rigorous acceptation. It may be said that the first contact of the air with the skin of the new-born infant causes severe pain, which is the reason of its cries. I believe, however, that this idea is unfounded.

* There is now in Paris a young artist who has no trace of fore-arms or hands. He has but four toes to his feet, the second being wanting; yet he is remarkable for his intelligence; he is even possessed of decided talent. He designs and paints with his feet; we may add, that these parts possess a sensibility and flexibility much more developed than is usual. It is certainly surprising that one so little favoured by nature should possess taste and talent as an historical painter.

Sensation and touch grow more obtuse with the progress of age. In old age they are sensibly diminished; at this period the skin undergoes changes which are unfavourable to this sense. The epidermis is no longer soft and flexible, the cutaneous transpiration is not abundant, the fat which before sustained the skin is absorbed, and it becomes flaccid and rugous. We can easily imagine that all these causes will impair the functions of sensation and touch, especially when we recollect that the power of receiving impressions generally becomes perceptibly diminished in old age.

By the exercise of this sense, it may be brought to a very great degree of perfection, as is observed in many professions. A delicate touch is indispensable both in a physician and surgeon.

Of Internal Sensations.

All the organs, like the skin, possess the faculty of transmitting to the brain impressions, when they are brought in contact with foreign bodies, or when they are compressed or bruised. They may be said, generally, to possess sensation. We must except, however, from this remark, the bones, tendons, aponeuroses, and ligaments, which in a state of health are totally insensible, and may be even cut, burned, or torn, without the brain being affected by it.* It seems incredible, according to the prevailing ideas on such subjects, that many of the nerves, as well as the tendons, aponeuroses, &c., are also insensible to all mechanical excitants. This holds true with respect to the first, second, third, fourth, sixth, and the portio mollis of the seventh pair of nerves, and the branches of the great sympathetic.†—(See *Expts.*, *Journ. de Phys.*, t. iv.) This important fact was not known by the ancients; they considered all the white parts of the body as nervous, and attributed to them properties which we now know only pertain to the nerves. It is to the experiments of Haller and his disciples that we are indebted for this useful information, which has exerted a powerful influence upon the progress of modern surgery. Indeed, before this unsuspected fact was ascertained by direct experiment, the great fear of surgical operators was wounding these white parts. At present no such apprehensions exist; this is a striking illustration of the great value of physiological experiments on living animals. How many individuals owe

* I have remarked, however, frequently in my experiments, that the part of the dura-mater that forms the walls of the superior longitudinal sinus possesses undoubted sensibility.

† The portio-dura of the seventh pair, or facial nerve, has some peculiarities in this respect. It does not appear to possess sensibility in itself; but if it is laid bare in a living animal, it exhibits unequivocal indications of sensibility. But M. Eschriht, professor of physiology at Copenhagen, has proved, by many nice experiments, that if this nerve possess sensibility, it depends, like all the nerves of the face, on the integrity of the fifth pair. This may also be inferred from an experiment made by myself, in which I cut both trunks of the fifth pair within the cranium. The whole face immediately lost its sensibility; of course that of the seventh was included; but the idea of drawing this inference did not occur to me. Fortunately for science, my learned friend did so, and made the subject the special object of his researches.

their life to the confidence which this knowledge has given to the surgeon! The fact that I had the happiness to discover, viz., that certain nerves, as well as the tendons, aponeuroses, cartilages, &c., are destitute of sensibility, will, I trust, have no less influence on the future progress of surgery.

Without the intervention of any external cause, all the organs may spontaneously transmit a great number of different impressions to the brain. They are of three kinds.

The first arises when there is a necessity that the organs should act; these may be called *instinctive desires.* Such are hunger, thirst, a desire to pass urine, respiration, and the venereal appetite.

The second takes place during the action of the organs; they are often obscure, but sometimes very vivid. Of this number are the impressions which accompany the different excretions, the impressions which we perceive during the period of digestion; thought itself may be included among this sort of impressions.

The third kind of internal sensations takes place when the organs have acted. To this kind belong the sensation of fatigue, varying, of course, according to the part affected.

It is necessary to add to these three kinds of impressions, those which arise from disease; these are very numerous, and a profound acquaintance with them is indispensable to the physician. All the sensations which arise from within, independently of the action of external bodies, have been designated as *internal sensations.* Their consideration was neglected by the metaphysicians of the last century, but their study has of late engaged the attention of many distinguished authors, particularly of Cabanis and M. Destutt Tracy; their history constitutes one of the most curious parts of ideology.

Of a supposed sixth Sense.

Buffon, in speaking of the intensity of those agreeable sensations which are produced by the approach of the sexes, has observed, in figurative language, that they depended on a sixth sense. The professors of animal magnetism, especially those of Germany, talk much of a sense which remains awake when the rest are asleep; that it is particularly developed in those persons who are called somnambulists, and that it gives to them the power of predicting future events. This sense, it is pretended, forms that instinct of animals by which they become acquainted with dangers which are near, and that it resides in the bones, viscera, ganglions, and the nervous plexus. To attempt to answer such reveries would be only to throw away one's time.

M. Jacobson having discovered in the *os incisivum* of animals a particular organ, suspected that it might be the source of a distinct order of sensations; but he has given no proof of this.

The faculty which bats have of directing their flight in the darkest places, has induced Spalanzani, and M. Jurine, of Geneva,

to think that these animals are possessed of a sixth sense; but M. Cuvier has shown that this power of conducting themselves in the dark is attributable to the sense of touch. There is, therefore, no evidence of a sixth sense.

CHAPTER VIII.

OF SENSATIONS IN GENERAL.*

Sensations form the first part of the life of relation; they establish our *passive relations* with surrounding bodies. This expression *passive*, as any one will easily perceive, is true only in a limited sense; for sensations, as well as the other functions of the economy, are the result of the action of the organs, and, of consequence, are essentially *active*. Every substance which exists is capable of acting upon our senses; we cannot know positively of their existence but in this way. Sometimes they act directly upon our organs; at others, through the medium of other bodies, as light, odours, &c.

The greater number of bodies act upon several of our senses; others, again, only affect one. The organs of sensation are formed of an exterior part, which exhibits physical properties in common with other bodies, and of nerves, which receive impressions and transmit them to the brain. The exterior parts of the apparatus of vision and hearing are very complicated; those of the others are very simple. But in all, the relation between their physical condition and other bodies is such, that the least alteration in that condition causes a marked derangement of function.

Nerves.

The nerves, which form the second part of the instruments of sensation, are the *essential organs of sense.* All the nerves have two extremities; the one is confounded with the substance of the brain, the other variously arranged in the organs. Each of these extremities has in turn been called the origin and termination of the nerves. Some say that all the nerves arise in the brain, and terminate in the organs; others, that they arise in the organs, and, by uniting, form the brain. These modes of expression are both improper, and convey very false ideas. They can be only useful in the description of the organs; but, as other expressions may easily be substituted, without at all obscuring the subject, it is desirable that they should be abandoned. It is evident enough that the brain is not formed by the union of the nerves, and it is

* These general sensations being founded on our knowledge of particular facts, we shall introduce them after having explained these facts. This course is conformable to the manner in which our ideas are formed.

equally certain that the nerves do not arise from the brain. By these expressions we merely mean to describe, metaphorically, the disposition of the two extremities of each nerve.

[It was formerly supposed that the same nervous filament executed several different offices, as receiving impressions from without, transmitting them to the sensorium, communicating the mandates of the will, and producing muscular motion. The unsoundness of this doctrine has been established, especially by the investigations of Sir Charles Bell. "No organ," says he, "which possesses only one endowment has more than one nerve, however exquisite the sense or action may be. But if two nerves are directed to one part, it is a sign of a double action performed by it. If a part or organ have many distinct nerves, we may be certain that, instead of having a mere accumulation of nervous power, it possesses several distinct powers, or enters into different combinations in proportion to the number of its nerves."

The property imparted appears to depend upon the organization of the nerve, the part of the encephalon from which it is derived, and the structure of the part to which it is distributed. Thus the filaments which bestow voluntary motion are supposed by Sir C. Bell to be derived from the cerebrum; those which bestow sensation, from the cerebellum. The greatest exactitude appears to be indispensable in the distribution of the nerves. It is a matter of comparatively little importance what particular arterial branch conveys blood to a part, or what vein takes it away, as the circulating fluid is the same. Hence, great irregularity in the distribution of the bloodvessels, without its causing disturbance of the functions, is often noticed. But assuming the facts stated above to be true, it is evident that the slightest deviation in the distribution of the nerves would be attended with serious inconvenience to the functions. A filament of motion, for example, can only bestow this property on a part so constituted as to possess an aptitude for contraction, as muscular fibre, and would be unavailable if distributed to any other structure, &c. Hence, as was observed by Sir Charles Bell, if we make a minute dissection of the nerves of the face, for example, the innumerable branches exposed appear to run in all directions, like the arteries and veins, without regularity or order. But when carefully compared in a great number of subjects, taken from all the different varieties of the human species, we find that every ganglion, trunk, and twig presents with great exactitude the same arrangement.]

The cerebral extremity of the nerves is composed of very fine and loose filaments, which are continued into the substance of the brain, for a short distance from the point where they are first perceived; these filaments, when united, form the nerve.

There is a marked difference between the nerves. Some are rounded, others flattened, others hollowed out at their sides, a great number are very long, and others very short. It may be asserted that, in form, colour, &c., there are no two nerves which exactly resemble each other. In general, they are so placed as

not to be exposed to injuries from external causes. In going to the different parts, the nerves divide into large, and afterward into smaller branches; and they terminate by filaments, so small, in the substance of the organs, that they cannot be distinguished, even by the assistance of the most powerful optical instruments. The nerves communicate among themselves, they anastomose, and thus form what is called a *plexus*.

With the exception of the optic nerve, the *organic extremity* of which can be easily distinguished, and of the auditory nerve, of which we have tolerably correct notions, we are absolutely ignorant of the disposition of the extremities of the nervous filaments in the tissue of the organs. We hear much of the *nervous extremities*, *papillæ*, &c. Physiologists are still in the habit of using these expressions; but all that is said on this subject is purely imaginary. It is easy to demonstrate that those bodies which have been, and are still, called *nervous papillæ*, do not exist.

The nerves are, in general, formed of filaments, excessively delicate, which are probably reducible into still finer filaments, if our means of division were more perfect. These filaments, which have been called nervous fibres, communicate frequently with each other, and effect, in the body of the nerve, an arrangement similar to what is found in a plexus. It is generally supposed that a fibre is formed by an envelope and a central pulp, similar in its nature to cerebral substance, but I believe that this is merely hypothetical. I have done all in my power to repeat the preparations advised by anatomists to display this structure, but, with all my efforts, I have never been able to distinguish it. The tenuity of the nervous fibres alone appears to me to be a most powerful objection to it. Since with the aid of a microscope we can scarcely perceive the fibre itself, and may reasonably suppose that this is formed by fibres still more delicate, how, I would inquire, is it possible to distinguish a cavity filled with pulp?

Some years since, M. Bogross, a very expert anatomist, thought he had injected the nerves with mercury, by means of strong compression, but he had merely forced the injection under the neurilema, which included a great number of nervous fibrillæ.*

Whatever may be the disposition of the substance which forms the parenchyma of the nervous fibres, it is certain that it possesses the same chemical properties as the cerebral substance, and that each nerve receives very numerous small branches of arteries, in proportion to its volume, and a proportionate number of small veins.

The posterior branches of all those nerves which arise from the spinal marrow present, not far from the point where they unite with the anterior branch, an enlargement, which is called a *ganglion*. These bodies are of a colour, consistence, and structure

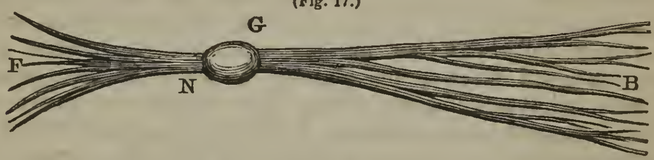
* I once saw, in the centre of the internal nerve of the penis of a horse, an appearance of a canal. Supposing that this appearance would be discoverable in other horses, I made every arrangement to attempt to inject it, but I never discovered it again. It was, no doubt, an accidental appearance.

essentially different from those of the nerves; their use is unknown.

[They are of a rounded form, pinkish colour, of considerable density, in their general structure are very vascular, and somewhat resemble the nerves. When cut, they have been thought to present an appearance like the gray substance of the brain. The only portion of the cerebro-spinal nerves in which they are found are what are called the *regular nerves*, viz., the spinal, including the fifth pair, or trigeminus, and the sub-occipital, which are more particularly destined to general sensibility. Numerous ganglia are also found attached to the great sympathetic nerve. The functions of these bodies are but little understood, and merit the particular attention of physiologists. Their study in living animals may lead to important discoveries connected with the offices of the nervous system.

The following diagram exhibits a portion of nerve connected with a ganglion.

(Fig. 17.)



G is the ganglion, N the nerve, which is seen to divide into numerous filaments at B and F.

The next figure, A, is a representation, from Wagner, of the primitive fibres and ganglionic globules which form a ganglion of the great sympathetic, magnified 350 diameters.

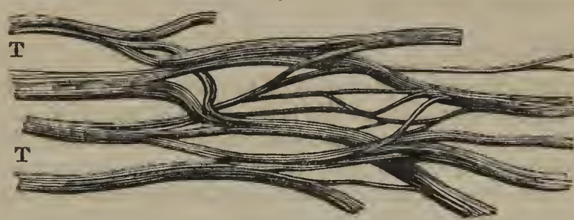
(Fig. 18.)

From the investigations of Sir Charles Bell, it would appear, as has been already stated, that every nervous fibre, or elementary filament, runs directly from the central nervous mass, where it originates, to the muscle, organ of sense, or other part in which it terminates. What are called the *trunks* of the nerves, according to him, consist of fasciculi, or bundles, of these nervous fibres or elementary filaments, some of which are *sensory* and others *motor*. These fasciculi occasionally intermix and exchange fibres with each other, forming a *plexus;* but the elementary fibres never

inosculate, each remaining distinct, and performing its appropriate office. The fasciculi are rolled up into trunks, and included in a common covering called the *neurilema*, merely for convenience of distribution.

The following figure will give an idea of those interlacings called a plexus. Four nerves, T T, are divided into branches, which are variously separated and reunited.

(Fig. 19.)



Of the offices performed by the ganglia of the great sympathetic nerve little is known at the present day. The striking views taken of this subject by Bichat, that they were centres from which the great sympathetic nerve derived its nervous energy, and that its offices were executed to a great degree by the ganglia, independently of the encephalon, produced an influence upon the profession which is, even now, strongly felt. This is shown by the name given by him, *ganglionic system of nerves*, which, though obviously objectionable, from its seeming to indicate the great sympathetic as the only class of nerves which have ganglia, is still retained in common use. But when we examine the highest modern authorities, we find directly contradictory statements as to their utility and functions. Bichat states that he irritated the cœliac ganglion, both mechanically and by chemical stimuli, without exciting pain. Dupuy cut out the inferior ganglion of the neck and the first ganglion of the thorax without causing suffering to the animals; he also states that the wound closed up without being followed by an appreciable alteration of function in the parts to which filaments were distributed coming from these ganglia. The observations of Lobstein agree with the foregoing. On the contrary, Flourens always observed, more or less, signs of pain. In Brachet's experiments there were sometimes manifestations of pain, and sometimes none. Mayer states that, both when the superior cervical ganglion was divided, and when the solar plexus was irritated, the animals gave distinct evidences of pain, which is also confirmed by Müller.* From these statements it appears that, in the present state of knowledge, it is very doubtful if the ganglia are concerned in the production of sensation, motion, and other properties which exist in those organs, the nerves of which are chiefly derived from the great sympathetic. But inasmuch as each of the compound nerves, on passing from the medulla spi-

* See page 712, vol. i.

nalis, directly communicates with the ganglia of the great sympathetic arranged along the sides of the vertebral column, it would seem probable that sensitive and motor filaments are sent off from these sources, and distributed with the filaments of the great sympathetic. According to this view, instead of supposing that the great sympathetic bestows several different properties, as sensation, motion, nutrition, &c., we have the more probable supposition that motion and sensation in these parts are derived from the cerebro-spinal system.*]

Of the Mechanism, or Physiological Explanation of Sensations.

The physiological explanation of sensations consists in the more or less exact application of the laws of physics and chemistry to the physical properties of that part of the organ which is placed before the nerves, as has been remarked in the particular history of each sensation. The moment we arrive at the use of the nerves in these functions, no farther explanation can be given. It is necessary to adhere rigorously to *facts.*

This consequence, so easy to deduce, does not seem to have been perceived but by a very small number of authors, and even in their works it is expressed very vaguely. All have endeavoured to explain the action of the nerves. The ancients considered these organs as the conductors of the animal spirits. At the period when physiology was governed by mechanical ideas, the nerves were supposed to be vibratory chords, although their physical condition is such as to prevent their vibration.

Some very intelligent men have supposed that the nerves were conductors, and even the secretory organs of a subtle fluid, which they have called *nervous.* According to them, sensations are transmitted to the brain by means of this fluid. At this moment, when the attention is directed towards the imponderable agents, this opinion has attracted numerous disciples. I am acquainted with men, who confer honour on the age by their genius and learning, who are inclined to admit that electricity exerts a considerable influence on the sensations and other functions. To

* Why should we consider the great sympathetic as a nerve? The ganglions and filaments which pass from it or lead to it have no analogy with the nerves, properly so called. Their colour, form, consistence, disposition, structure, and chemical properties are all different; nor have they any greater analogy in their vital properties. We may scratch or cut a ganglion, or even tear it, without the animal appearing to be conscious of it. I have often made these experiments on the ganglions in the necks of horses and dogs. Similar operations performed on a cerebral nerve will produce the most terrific pain. We may take away all the ganglions of the neck, and even the first ganglions of the thorax, without any sensible derangement in the functions even of those parts to which we can trace them. What reason is there, then, for considering the system of ganglions as constituting a part of the nervous system? Would it not be more philosophical, and especially more useful to the future progress of physiology, to acknowledge that, at this moment, the uses of the great sympathetic are entirely unknown? We shall be confirmed in this idea by reading on the subject. Every author has some peculiar opinions on this point. We hear, *e. g.*, the ganglions considered as nervous centres, small brains, collections of cineritious substance for the nourishment of the nerves, &c. If we inquire after the proof by which these authors establish their doctrines, we are surprised not to find any, but that their assertions are mere freaks of the imagination. It appears to me that the functions of these singular organs, so intimately connected with the nerves, have not yet been discovered, but which may become unveiled to him who will take the trouble to interrogate nature by delicate and ingenious experiments.

pretend to explain the sensations by referring them to certain vital properties, which are called *animal, perceptive, relative*, &c., is to have recourse to a most vicious mode of explanation: it is only a new way of expressing the difficulty; it by no means solves it. We shall, therefore, class the action of the nerves among the *vital actions*, which, as has been seen at the commencement of this work, are not susceptible of explanation in the present state of science; but that the nerves are the agents for the transmission of those impressions which are received from the senses, is conclusively demonstrated by observation and experience.

Thus, if a man receive a wound which affects a nervous trunk, the part to which the nerve is distributed becomes insensible. If the optic nerve be the one which has suffered, the individual will become blind; and if the auditory, deaf. We may produce these effects at any time upon brutes by dividing, or, even simply, by compressing the nerves. When the compression is removed, the nerve is restored to its sensibility as before. In man, as in brutes, the wounding of a nerve produces severe pain. In a word, all those diseases which alter, even slightly, the tissue of the nerves, have a manifest influence upon their action, as agents of sensation.

Science has recently made great progress, as respects the functions of the nerves: the views formerly entertained on this subject have undergone an entire reform. The nerves are now distinguished into *sensible* and *insensible*. The nerves of sensation are anatomically distinguishable by a ganglion situated near their origin. These nerves consist, 1st. Of the superior branch of the fifth pair, which imparts sensibility to the integument and mucous membranes of all the anterior part of the head. 2d. Of the nerves which result from the union of the posterior roots of the spinal nerves. They impart sensibility to the skin of the neck, trunk, extremities, and almost all the organs of the breast and abdomen. 3d. Of the nerves of the eighth pair, which preside over the sensibility of the pharynx, œsophagus, larynx, and stomach. 4th. Of the sub-occipital, or tenth pair, which presides over the sensibility of the posterior part of the head, and a part of the external cartilage of the ear.

I have proved, by direct experiment, that if these different nerves are cut near their origin, the parts to which they are distributed lose their sensibility.

The nerves that may be regarded as *insensible* (though this expression does not absolutely hold true, inasmuch as among them are found the principal nerves of special sensation, those of seeing and hearing) are the optic, olfactory, and acoustic. But we have already seen that these three nerves have a special sensibility, which is, in great part, under the influence of the fifth pair. The knowledge of this influence of one nerve over the action of others is new in science, and is worthy the particular attention of physiologists.

Many other nerves appear also to be destitute of sensibility; such are the third, fourth, and six pairs, the portio dura of the seventh, with the particular modifications above indicated; the hypoglossal nerve, and the anterior branch of all the compound nerves which arise from the medulla spinalis. If these nerves be divided, the parts to which they are distributed still preserve their sensibility. In man, in a state of disease, when these nerves are alone interested, many functions are disturbed, but the faculty of sensation is not diminished.

We are quite ignorant of the utility of the numerous anastomoses of the nerves; nor do we better understand the consequences which result from the communications between the nerves of sensation with the ganglions of the great sympathetic. The suppositions that have been made to explain their use show sufficiently that, on this point, physiology is still in its infancy.

Thus far, we have only spoken of the agents of sensation; let us next inquire respecting the phenomenon itself, describe its principal characters, and point out the most remarkable.

Every sensation, at the moment when we experience it, is referred to an external cause. We know that the impression perceived arises from something that is not a part of ourselves, or, as some would say, *from the external world;* so that to perceive an impression is at the same time to know, 1st. That it arises from some cause. 2d. That this cause is exterior to ourselves.* This surprising result is not the isolated work of the special organs of sensation; it is the first, as the most important, of the acts of the understanding, which I call *instinctive*, and, consequently, the product of the combined action of the brain and organs of the senses. To conjecture what takes place in the nervous system when we experience a sensation, transcends the human understanding. Nevertheless, such is our irresistible disposition to form images wherever there is obscurity, that we imagine each sensation as resulting from the successive, but very rapid, development of a certain number of phenomena. Thus, in every sensation there is supposed to be the following acts: 1st. The action of the cause upon the sense. 2d. The action of the nerve to transmit it. 3d. The impression received by the cerebral centre. 4th. The instinctive reaction, which informs us that the cause of the sensation is exterior to us; often at a considerable distance, having as an intermediate agent air, light, or heat. Such is the image or idea that metaphysicians have formed of every complete sensation, to which some of our most learned ideologists have recently consecrated the word *perception.*

But is this very nice analysis, by which a sensation is divided into so many elements, *real?* Is it possible to prove, physiologically, these successive acts in an instantaneous phenomenon, and that the simplest known? Does not the mind, impatient of doubt in proportion to our ignorance, impose upon itself this analytical

* We here refer to sensations, properly so called, and not to internal sensations, which hereafter will be examined in this point of view.

romance, as in many other instances we mask our ignorance with the mere appearance of truth? According to the experimental method that we hope always to pursue in these investigations, the sensation, and, consequently, its relations with the exterior cause, are to us a singular phenomenon, the same and indivisible as respects time or separate acts. It is not less possible that the nervous system perceives at its surface than its centre.

The same instinct which induces us to place the cause of our sensations exterior to ourselves, leads us also to inquire, what is this cause, and what are its characters? To arrive immediately at this knowledge constitutes one of our most urgent desires and most vivid pleasures. When, by a concurrence of circumstances, or from the nature of the cause of our sensation, it is impossible to recognise it, we feel anxiety, and make great efforts for this purpose; and when we accomplish it, we experience great satisfaction.

Sensations are either vivid or weak. The first time a body acts upon our senses, the impression produced is generally vivid. The vivacity of the impression diminishes, if the action of the body be frequently repeated, and, at last, it is scarcely perceived. This fact is expressed when we say that *habit blunts our feelings.* The existence of man being, as it were, measured out by the vivacity of his sensations, he is induced to seek continually for new impressions, which are always the most vivid; hence his inconstancy, inquietude, and *ennui*, if he remain long exposed to the same causes of sensation.

We possess the power of rendering our sensations more vivid and distinct. In order to do this, we dispose the organ of sense in the most favourable manner, we receive but a small number of sensations at a time, and we direct all our attention to them; thus arises the important difference between seeing and examining, hearing and listening, the common exercise of the sense of smell, and snuffing, &c. Nature has also given us the power of diminishing our sensations. Thus we draw down the eyebrows, and close the eyelids, when the impression produced by the light is too vivid; we breathe through the mouth when we wish to diminish the effect of a strong odour, &c.

The different sensations also direct, assist, modify, and may even mislead each other. Smell seems to be the sentinel and guide to taste, and taste, in its turn, exerts a powerful influence over smell. Smell may exercise its functions separately from those of taste, but the reverse cannot be always done, as the aliments and drinks cannot pass into the mouth without acting, more or less, upon the nose; whenever their taste is very disagreeable, their odour soon becomes so; again, those aliments, the odour of which is most unpleasant, soon loose this quality when the taste very vehemently desires them.*

We know, from numerous observations, that the vivacity of the impressions received by the senses is increased by the loss of one

* Cabanis.

of these organs. For example, the smell is more delicate in blind or deaf persons than in those who enjoy all their senses. I think, however, that the absence of smell, which we often meet with, does not give any increased activity to the other senses.

We have a curious history of a young man, born deaf and blind, who was observed by a number of scientific persons.

James Mitchel was born the 11th of November, 1795, deaf and blind, but he experienced pleasure in rubbing hard bodies upon his teeth. He amused himself in this way, sometimes, for hours. He could distinguish day from night, and a few colours, red, white, and yellow. In his youth he amused himself by looking through the windows at the sun, and the light of the fire. His relations with surrounding bodies were principally established by smell and touch. At the age of fourteen years, M. Wardrop performed the operation of cataract on the right eye, which somewhat improved his imperfect vision. After this, he had less frequently recourse to the sense of smell. He handled bodies in all directions with his head bent, as we observe in blind people. His desire to become acquainted with surrounding objects, as their quantities, uses, &c., was very vivid. He examined everything that came in his way, men, animals, and things; his actions indicated reflection. One day, the shoemaker brought home a pair of shoes for him that were too small; his mother locked them up in a cabinet, and took the key. In a short time afterward, James asked his mother for the key by turning his hand. His mother gave it him, when, unlocking the cabinet and taking the shoes, he put them upon the feet of a little boy, who accompanied him in his excursions, and whom they fitted very well. During his infancy, he smelled all those who approached him, putting their hands to his nose, and snuffing the air. Their odour determined his liking or repugnance to them. He recognised his clothes by the smell, and was averse to use those of another; bodily exercises amused him.

His countenance was very expressive; his natural language that of an intelligent being. When he was hungry, he carried his hand to his mouth, and pointed to the closet where the food was kept. When he wished to lie down, he laid his head upon his hand. He imitated different employments, when he wished to indicate them, as the different motions of a shoemaker, a tailor, &c. He delighted in being placed on horseback, which he designated by joining his hands, and then placing them on the soles of his feet, to imitate a stirrup. He did not like to be embraced, and when his sister sometimes did so to amuse herself, he seemed annoyed by it. It was remarkable that all the signs he invented were intended for the sight of others. He appeared to know his inferiority in respect to this sense. He was usually accompanied by a little boy in his excursions, and was allowed to go wherever he chose; if he met with any object that was unknown to him, he waited until the arrival of his companion. He recognised readily the signs that were made to him. To make

him understand the number of days, they inclined his head upon his hand, as a sign that he would sleep so many nights before the event would happen. They testified their approbation by caressing him, their dissatisfaction by tapping him a little sharply. He was much gratified by the caresses of his parents; he loved young infants, and was fond of holding them in his arms. He was naturally kind and inoffensive, but his temper was not equal. Sometimes he was pleased to have persons play with him, and laughed heartily. One of his favourite amusements was to shut some one in a chamber, or in the stable. If he was opposed much, he uttered very disagreeable cries. He appeared generally contented.

He possessed courage, naturally, but acted prudently. One day, he found in his way a narrow wooden bridge, which passed over a stream near his father's house. He got on his hands and knees to pass it. His father, in order to intimidate him, sent a man to push him into the water, at a place where there was no danger, and to take him out immediately. This lesson produced the desired effect; he never went to the bridge again. Some years afterward, he recollected this punishment. One day, his little companion having displeased, him while they were playing together in a boat secured to the bank of the stream, he plunged him in, and then drew him out.

[The following case, reported by Dr. Howe, of Boston, furnishes a number of still more striking physiological and psychological results.

Laura Bridgman was born in New-Hampshire, December 21st, 1829. Her health was very infirm, being subject to fits until she was a year and a half old. After a temporary improvement, she was attacked by a severe disease, the consequence of which was destruction of the organs of hearing and vision, and confinement to her room, and chiefly to her bed, for nearly two years. As soon as her health was restored and she was enabled to walk about, she gave strong indications of intelligence and warm affections, though the means of communication with her were very limited. She could only be told to go to a place by being pushed, or to come to one by drawing her; patting her gently on the head indicated approbation; on the back, disapprobation. In October, 1837, then aged about eight years, she was brought to Boston and placed in the Perkins Institution for the Blind, under the care of its philanthropic director, Dr. Howe, to whom we are indebted for the interesting developments which mark this extraordinary case. For a time, she seemed bewildered, and it was thought prudent to wait for about two weeks, until she could become familiarized with her kind teacher and friend, and her new locality, before making any systematic attempt to develop her faculties by education.

"There were," says Dr. Howe, "two ways to be adopted: either to build up a language of signs, on the basis of the natural language, which she had already commenced; or to teach her the

purely arbitrary language in common use, *i. e.*, to give her a knowledge of letters, by combination of which she might express her idea of the nature and mode of existence of anything. The former would have been easy, but very ineffectual; the latter seemed very difficult, but, if accomplished, very effectual. I determined, therefore, to try the latter."

The results of this attempt have been furnished by Dr. Howe in the annual reports of the trustees of the Perkins Institution and Massachusetts Asylum for the Blind, from that time to the last annual report, 1842, from which the present account is extracted.

The first experiments were taking articles in common use, as spoons, knives, keys, &c., and pasting upon them labels of their names in raised letters, as used for the blind. She soon learned to distinguish that the crooked lines upon the spoon differed from those upon the key. Then the labels were detached, and she showed her perception of their relation by placing the label *key* upon the key, and *spoon* upon the spoon. It was evident, however, that the only intellectual exercise was that of imitation and memory. At last, instead of labels, the individual letters, on detached pieces of paper, were given to her. They were arranged side by side so as to spell *spoon*, *key*, &c. They were mixed up, and she was desired, by a sign, to arrange them herself, which she did.

Heretofore, says Dr. Howe, the process had been mechanical, and the success about as great as teaching a very docile dog a variety of tricks. The poor child had sat in mute amazement, and patiently imitated everything her teacher did; but now the truth began to flash upon her; her intellect began to work; she perceived that there was a way by which she could herself make up a sign of anything that was in her own mind, and communicate it to another mind. It was no longer the act of a dog or parrot, but that of a reasoning spirit, eagerly seizing upon a new link of union with other spirits of its kind. I could, says he, almost fix upon the moment when this truth dawned upon her and spread its light over her countenance. This, though briefly told, required many weeks of patient and persevering effort on the part of her kind teacher. From this moment, says he, I perceived that the great obstacle was overcome, and that henceforward nothing but plain and persevering exertion would be necessary.

He next procured a set of metal types with the letters of the alphabet, and a board into which they might be conveniently set, and thus she could arrange the letters of the few words she knew and read them, which she appeared to do with great pleasure. After weeks of persevering instruction with this apparatus, until she had acquired an extensive vocabulary, this cumbrous arrangement was laid aside, and the manual alphabet of deaf mutes taught her in its place. This she accomplished speedily and easily, for her intellect had begun to work in aid of her teacher, and her progress was very rapid. The manner of proceeding was thus. The teacher gave her a new object, *e. g.*, a pencil; first, he let her examine it, and get an idea of its use. Then he

taught her how to spell it, by making the signs for the letters with her own fingers. "The child," says he, "grasps her hand, and feels of her fingers, as the different letters are formed—she turns her head a little on one side, like a person listening closely—her lips are apart—she seems scarcely to breathe—and her countenance, at first anxious, gradually changes to a smile as she comprehends the lesson. She then holds up her tiny fingers and spells the word in the manual alphabet; next she takes her types and arranges the letters; and last, to make sure that she is right, she takes the whole of the types composing the word, and places them upon or in contact with the pencil or other object.

"The whole of the succeeding year was passed in gratifying her eager inquiries for the names of every object which she could possibly handle; in exercising her in the use of the manual alphabet; in extending, in every possible way, her knowledge of the physical relations of things; and in proper care of her health."

At the end of the year, a report of her case was made, from which the following is an extract:

"It has been ascertained, beyond the possibility of doubt, that she cannot see a ray of light, cannot hear the least sound, and never exercises her sense of smell, if she has any. Thus her mind dwells in darkness and stillness, as profound as that of a closed tomb at midnight. Of beautiful sights, and sweet sounds, and pleasant odours, she has no conception; nevertheless, she seems as happy and playful as a bird or a lamb; and the employment of her intellectual faculties, or acquirement of a new idea, gives her a vivid pleasure, which is plainly marked in her expressive features. She never seems to repine, but has all the buoyancy and gayety of childhood. She is fond of fun and frolic, and, when playing with the rest of the children, her shrill laugh sounds loudest of the group.

"When left alone, she seems very happy if she has her knitting or sewing, and will busy herself for hours; if she has no occupation, she evidently amuses herself by imaginary dialogues, or by recalling past impressions; she counts with her fingers, or spells out names of things which she has recently learned in the manual alphabet of the deaf mutes. In this lonely self-communion, she seems to reason, reflect, and argue: if she spells a word wrong with the fingers of her right hand, she instantly strikes it with her left, as her teacher does, in sign of disapprobation; if right, then she pats herself upon the head, and looks pleased. She sometimes purposely spells a word wrong with the left hand, looks roguish for a moment and laughs, and then with the right hand strikes the left, as if to correct it.

"During the year, she has attained great dexterity in the use of the manual alphabet of the deaf mutes, and she spells out the words and sentences which she knows so fast and so deftly, that only those accustomed to this language can follow with the eye the rapid motions of her fingers.

"But wonderful as is the rapidity with which she writes her

thoughts upon the air, still more so is the ease and accuracy with which she reads the words thus written by another, grasping their hands in hers, and following every movement of their fingers, as letter after letter conveys their meaning to her mind. It is in this way that she converses with her blind playmates; and nothing can more forcibly show the power of mind in forcing matter to its purpose than a meeting between them; for, if great talent and skill are necessary for two pantomimes to paint their thoughts and feelings by the movements of the body and the expression of the countenance, how much greater the difficulty when darkness shrouds them both, and the one can hear no sound!

"When Laura is walking through a passage-way, with her hands spread before her, she knows instantly every one she meets, and passes them with a sign of recognition; but if it be a girl of her own age, and especially if one of her favourites, there is instantly a bright smile of recognition and a twining of arms, a grasping of hands and a swift telegraphing upon the tiny fingers, whose rapid evolutions convey the thoughts and feelings from the outposts of one mind to those of the other. There are questions and answers, exchanges of joy or sorrow; there are kissings and partings, just as between little children with all their senses.

"During this year, and six months after she had left home, her mother came to visit her, and the scene of their meeting was an interesting one.

"The mother stood some time gazing with overflowing eyes upon her unfortunate child, who, all unconscious of her presence, was playing about the room. Presently Laura ran against her, and at once began feeling of her hands, examining her dress, and trying to find out if she knew her; but, not succeeding in this, she turned away as from a stranger, and the poor woman could not conceal the pang she felt at finding that her beloved child did not know her.

"She then gave Laura a string of beads which she used to wear at home, which were recognised by the child at once, who, with much joy, put them around her neck, and sought me eagerly, to say she understood the string was from her home.

"The mother now tried to caress her, but poor Laura repelled her, preferring to be with her acquaintances.

"Another article from home was now given her, and she began to look much interested; she examined the stranger much closer, and gave me to understand that she knew she came from Hanover; she even endured her caresses, but would leave her with indifference at the slightest signal. The distress of the mother was now painful to behold; for, although she had feared that she should not be recognised, the painful reality of being treated with cold indifference by a darling child was too much for woman's nature to bear.

"After a while, on the mother taking hold of her again, a vague idea seemed to flit across Laura's mind that this could not be a stranger; she therefore felt of her hands very eagerly, while her

countenance assumed an expression of intense interest: she became very pale, and then suddenly red; hope seemed struggling with doubt and anxiety, and never were contending emotions more strongly painted upon the human face. At this moment of painful uncertainty, the mother drew her close to her side and kissed her fondly, when at once the truth flashed upon the child, and all mistrust and anxiety disappeared from her face, as, with an expression of exceeding joy, she eagerly nestled to the bosom of her parent, and yielded herself to her fond embraces.

"After this the beads were all unheeded; the playthings which were offered to her were utterly disregarded; her playmates, for whom, but a moment before, she gladly left the stranger, now vainly strove to pull her from her mother; and though she yielded her usual instantaneous obedience to my signal to follow me, it was evidently with painful reluctance. She clung close to me, as if bewildered and fearful; and when, after a moment, I took her to her mother, she sprang to her arms and clung to her with eager joy.

"Having acquired the use of substantives, adjectives, verbs, prepositions, and conjunctions, it was thought time to make the experiment of trying to teach her to *write*, and to show her that she might communicate her ideas to persons not in contact with her.

"It was amusing to witness the mute amazement with which she submitted to the process, the docility with which she imitated every motion, and the perseverance with which she moved her pencil over and over again in the same track, until she could form the letter. But when at last the idea dawned upon her that, by this mysterious process, she could make other people understand what she thought, her joy was boundless.

"Never did a child apply more eagerly and joyfully to any task than she did to this; and in a few months she could make every letter distinctly, and separate words from each other; and she actually wrote, unaided, a legible letter to her mother, in which she expressed the idea of her being well, and of her expectation of going home in a few weeks. It was, indeed, a very rude and imperfect letter, couched in the language which a prattling infant would use; still it shadowed forth, and expressed to her mother, the ideas that were passing in her own mind.

"She is familiar with the processes of addition and subtraction in small numbers. Subtraction of one number from another puzzled her for a time, but by the help of objects she accomplished it. She can count and conceive objects to about one hundred in number; to express an indefinitely great number, or more than she can count, she says *hundred*. If she thought a friend was to be absent many years, she would say *will come hundred Sundays*, meaning weeks. She is pretty accurate in measuring time, and seems to have an intuitive tendency to do it. Unaided by the changes of night and day, by the light, or the sound of any timepiece, she nevertheless divides time pretty accurately.

"With the days of the week, and the week itself as a whole, she is perfectly familiar: for instance, if asked what day will it be in fifteen days more, she readily names the day of the week. The day she divides by the commencement and end of school, by the recesses, and by the arrival of meal times.

"Those persons who hold that the capacity of perceiving and measuring the lapse of time is an innate and distinct faculty of the mind, may deem it an important fact that Laura evidently can measure time so accurately as to distinguish between a half and whole note of music.

"Her judgment of distances and of relations of place is very accurate. She will rise from her seat, go straight towards a door, put out her hand just at the right time, and grasp the handle with precision."

These extracts from former reports bring down the history of her instruction to the commencement of the year 1840, when she had been two years and two months under instruction.

In the next Annual Report, for 1841, she is stated to be eleven years of age, in good health. There was still no indication of her perceiving light or sound, with, perhaps, some slight but not essential improvement in the sense of smell. The touch had evidently improved in acuteness.

"Her mental perceptions, resulting from sensation, are much more rapid than they were, for she now perceives, by the slightest touch, qualities and conditions of things similar to those she had formerly to feel long and carefully for. So with persons: she recognises her acquaintances in an instant, by touching their hands or their dress; and there are probably fifty individuals who, if they should stand in a row, and hold out each a hand to her, would be recognised by that alone.

"The memory of these sensations is very vivid, and she will readily recognise a person whom she has once thus touched. Many cases of this kind have been noticed; such as a person shaking hands with her, and making a peculiar pressure with one finger, and repeating this on his second visit, after a lapse of many months, being instantly known by her. She has been known to recognise persons whom she had thus simply shaken hands with but once, after a lapse of six months.

"The moral qualities of her nature have also developed themselves more clearly. She is remarkably correct in her deportment, and few children of her age evince so much sense of propriety in regard to appearance. Never, by any possibility, is she seen out of her room with her dress disordered; and if, by chance, any spot of dirt is pointed out to her on her person, or any little rent in her dress, she discovers a sense of shame, and hastens to remove it.

"She is never discovered in an attitude or an action at which the most fastidious would revolt, but is remarkable for neatness, order, and propriety.

"There is one fact which is hard to explain in any way; it is

the difference of her deportment to persons of different sex. This was observable when she was only seven years old. She is very affectionate, and when with her friends of her own sex she is constantly clinging to them, and often kissing and caressing them; and when she meets with strange ladies she very soon becomes familiar, examines very freely their dress, and readily allows them to caress her; but with those of the other sex, it is entirely different, and she repels every approach to familiarity. She is attached, indeed, to some, and is fond of being with them; but she will not sit upon their knee, for instance, or allow them to take her around the waist, or submit to those innocent familiarities, which it is common to take with children of her age.

"She seems to have also a remarkable degree of conscientiousness, for one of her age; she respects the rights of others, and will insist upon her own.

"She is fond of acquiring property, and seems to have an idea of ownership of things which she has long since laid aside and no longer uses. She has never been known to take anything belonging to another, and never, but in one or two instances, to tell a falsehood, and then only under strong temptation.

"It has been remarked, in former reports, that she can distinguish different degrees of intellect in others, and that she soon regarded, almost with contempt, a new-comer, when, after a few days, she discovered her weakness of mind. This unamiable part of her character has been more strongly developed during the past year.

"She chooses for her friends and companions those children who are intelligent, and can talk best with her; and she evidently dislikes to be with those who are deficient in intellect, unless, indeed, she can make them serve her purposes, which she is evidently inclined to do. She takes advantage of them, and makes them wait upon her, in a manner that she knows she could not exact of others, and, in various ways, she shows her Saxon blood.

"She is fond of having other children noticed and caressed by the teachers and those whom she respects; but this must not be carried too far, or she becomes jealous. She wants to have her share, which, if not the lion's, is the greater part; and if she does not get it, she says, '*My mother will love me.*'

"Her tendency to imitation is so strong, that it leads her to actions which must be entirely incomprehensible to her, and which can give her no other pleasure than the gratification of an internal faculty. She has been known to sit for half an hour, holding a book before her sightless eyes, and moving her lips, as she has observed seeing people do, when reading.

"She one day pretended that her doll was sick, and went through all the motions of tending it and giving it medicine; she then put it carefully to bed, and placed a bottle of hot water to its feet, laughing all the time most heartily. When I came home, she insisted upon my going to see it and feel its pulse; and when I

told her to put a blister to its back, she seemed to enjoy it amazingly, and almost screamed with delight.

"Her social feelings and her affections are very strong; and when she is sitting at work, or at her studies, by the side of one of her little friends, she will break off from her task every few moments to hug and kiss them, with an earnestness and warmth that is touching to behold.

"When left alone, she occupies, and apparently amuses herself, and seems quite contented; and so strong seems to be the natural tendency of thought to put on the garb of language, that she often soliloquizes in the *finger language*, slow and tedious as it is. But it is only when alone that she is quiet, for if she becomes sensible of the presence of any one near her, she is restless until she can sit close beside them, hold their hand, and converse with them by signs.

"She does not cry from vexation and disappointment, like other children, but only from grief. If she receives a blow by accident, or hurts herself, she laughs and jumps about, as if trying to drown the pain by muscular action. If the pain is severe, she does not go to her teachers or companions for sympathy, but, on the contrary, tries to get away by herself, and then seems to give vent to a feeling of spite, by throwing herself about violently and roughly handling whatever she gets hold of.

"Twice only have tears been drawn from her by the severity of pain, and then she ran away, as if ashamed of crying for an accidental injury; but the fountain of her tears is by no means dried up, as is seen when her companions are in pain or her teacher is grieved.

"In her intellectual character, it is pleasing to observe an insatiable thirst for knowledge, and a quick perception of the relations of things. In her moral character, it is beautiful to behold her continual gladness, her keen enjoyment of existence, her expansive love, her unhesitating confidence, her sympathy with suffering, her conscientiousness, truthfulness, and hopefulness."

Her ideas of death are interesting. It appears that, before being brought to the institution, she had been taken to a funeral, and touched a dead body.

"She was acquainted with two little girls, sisters, in Cambridge, Adeline and Elizabeth. Adeline died during the year before last. Not long since, in giving her a lesson in geography, her teacher began to describe Cambridge; the mention of Cambridge called up a new subject, and she asked, '*Did you see Adeline in box?*' I answered, Yes. '*She was very cold, and not smooth; ground made her rough.*' I tried to change the subject here, but it was in vain; she wished to know how long the box was, &c.; she said, '*Drew told me about Adeline; did she feel? did Elizabeth cry and feel sick? I did not cry, because I did not think much about it.*' She then drew in her hands shudderingly, as if cold. I asked her what was the matter. She said, '*I thought about* (how) *I was afraid to feel of dead man before I came here, when I*

was very little girl with my mother; I felt of dead head's eyes and nose; I thought it was man's; I did not know.' Now, it is impossible that any one could have said anything to her on the subject; she could not know whether the state the man was in was temporary or lasting; she knew only that there was a human being, once moving and breathing like herself, but now confined in a coffin, cold, and still, and stiff, in a state which she could not comprehend, but which nature made her recoil from.

"During the past year, she all at once refused to eat meat, and being asked why, she said, '*Because it is dead.*' I pushed the inquiry, and found she had been in the kitchen and felt of a dead turkey, from which she suddenly recoiled. She continued disinclined to eat flesh for some weeks, but gradually she came to her appetite again; and now, although she understands that fowls, sheep, calves, &c., are killed to furnish meat, she eats it with relish."

We may conclude from these cases, though vision and hearing furnish many facts to the understanding, still that it may attain considerable development without their aid.

There is another singular and unexpected result lately observed. In ordinary circumstances, at the period of birth, the senses act with little skill; they are gradually developed by exercise, and at the age of a year, the infant has nearly the complete enjoyment of all his senses. But it sometimes happens that certain physical causes prevent the development of one of the senses, and this most frequently occurs to hearing. If these causes are of a nature to remain long, the individual loses all idea of sound, as in deaf mutes from birth. It has been long supposed that, if the obstacle to hearing in such cases could be removed, the individual would be situated like a new-born child, and that the hearing would become gradually developed by use as in other persons, and that if he had attained an age that rendered him capable of reflection, that the acquisition of a new sense would be most highly appreciated by him. But this does not appear to be the case. Several instances have been recently observed where deaf mutes have been restored to hearing at from ten to fifteen years of age. But they seemed to attach but little value to the new sense, and were not inclined to make much use of it. They were still disposed to continue to communicate by gestures, and to pay but little attention to sounds. In order that one deaf from birth may derive much advantage from hearing, a long and laborious course of education is indispensable, and still such individuals never use their hearing like one with all their senses perfect from birth.]

Sensations are *agreeable* or *disagreeable;* the first, when they are vivid, constitute *pleasure,* and the second *pain.* By pleasure and pain nature induces us to concur in the order which she has established among organized beings.

Though it may appear like sophistry to say that pain is but the shadow of pleasure, still it is certain that persons who have ex-

hausted all the sources of pleasure, and have thus become insensible to all ordinary sensations, have recourse to the causes of pain, and gratify themselves by their effects. Do we not see, in all large cities, that men who are debauched and degraded, find agreeable sensations where others experience nothing but the most intolerable pain?

It is necessary to remark, that those sensations which come from the senses are distinct. All our ideas, and the knowledge we have of nature, are thus received. Internal sensations, or sentiments, do not possess these characters. In general, they are confused, and often vague; we are not conscious of them; they are not engraved upon the memory, but are always more or less fugitive, especially when in health.

Whenever our organs act freely, and according to the ordinary laws of organization, our thoughts are agreeable, the pleasure is sometimes very vivid. But when the functions are deranged, the organs wounded, or diseases have impaired their action, our internal sensations are painful, according to the nature of the injury.

There is sometimes a degree of vivacity in these internal sensations which absorbs all our attention, so that we scarcely notice our external sensations. Those internal sensations arising from disorder of the functions are extremely varied, and generally different from those of health. We experience, as in external sensations, an instinctive disposition to refer them to some cause, and that cause has a place. But we often deceive ourselves, in believing the seat of the sensation to be in one part when it is really in another. In this respect, there are some illusions so uniform, that they are signs of a certain disease. Thus, in diseases of the hip joint, the pain is frequently altogether in the knee; a stone in the bladder causes pain about the *glans penis*. Thus pain and other sensations which accompany diseases become objects of great interest, in the studies of the physician.*

It is probable that the nerves which pass directly from the brain or spinal marrow are the organs for the transmission of internal sensations. The physiologists of the present day, however, appear to attribute this function to the nerve which is called the *great sympathetic*. We cannot say positively that it is not so, but it is impossible to admit this doctrine, as it is not founded on any fact or direct experiment.

The causes which modify internal and external sensations are innumerable. Age, sex, temperament, seasons, climate, habit, and individual character, each separately modify sensation; but when they are united, the result is much more manifest. The difference of sensations among different individuals is expressed by the common maxim, "Every one has his own way of feeling and thinking."

* After certain surgical operations, some strange illusions become developed. An amputated limb will seem to suffer. When the skin has been removed from the forehead to form an artificial nose, various sensations are observed, which are referred to the part from which the integument was taken.

It is probable that only internal sensations exist in the fœtus. We are led to suppose this by the motions which it executes, which appear to be the result of impressions arising spontaneously in the organs. It is well known, from experiment, that when any derangement arises in the circulation or respiration of the mother, it is followed by the motions of the fœtus. All the senses are not found to exist at birth, or for some time afterward. Taste, touch, and smell are alone exercised; sight and hearing are developed later, as we have observed in the history of each particular function. Each sense must pass through different degrees before it can arrive at perfection; it is indispensable, therefore, that each sense should receive what may properly be called an *education.* If any person will follow an infant in the development of its senses, he may easily satisfy himself of the modifications they undergo before arriving at perfection.

In those sensations which are produced by distant objects, the education is slow and difficult; in those which arise from contact, it is much more prompt, and appears to be easily effected. During this education of the senses, that is, in our infancy, the sensations are confused and weak; but afterward, especially those of young people, they are remarkable for their number and vivacity. At this age, they are deeply engraved in the memory, and, of consequence, are destined to constitute a part of our intellectual existence during the remainder of our lives. With the progress of age, our sensations lose their vivacity, but become more perfect, as respects exactness, after arriving at the adult age. In old age, they grow weak, and are produced with slowness and difficulty. This effect is more remarkable in those senses which make us acquainted with the physical properties of bodies, but much less so in those by which we become informed of their chemical properties. These last senses, those of taste and smell, alone preserve any activity in decrepitude; the others are nearly extinguished by the diminished sensibility and the successive physical alterations which they undergo.

CHAPTER IX.

OF THE FUNCTIONS OF THE ENCEPHALON.

The most sublime features in the human character are intelligence, thought, the passions, and that admirable faculty by which we are enabled to direct our movements, and communicate by speech. These phenomena are dependant upon the brain, and are designated by many physiologists as the *cerebral functions.* Other physiologists, sustained and inspired by religious creeds, regard them as belonging to the soul, a being de-

rived from the Divine essence, of which immortality is one of the attributes. It would not be becoming in us to undertake to decide here between these two modes of contemplating this important subject; our object is science, not theology. Besides, we do not pretend to explain the acts of the understanding or the instincts; our object is to study them, and to demonstrate the physiological connexion they may have with the brain generally, or with certain of its parts. We shall observe this method of studying the phenomena of the understanding, and thus endeavour to avoid some of the errors into which those have fallen who have pursued a different course.

Under the denomination of encephalon I include three parts, distinct from each other, though they are all united at certain points; they are the *cerebrum*, *cerebellum*, and *medulla spinalis.*

In each of these principal divisions we find distinct parts which have a sort of separate existence, so that there is nothing more complicated and difficult in anatomy than the study of the organization of the encephalon. In proportion, however, to the importance of the function of this organ, anatomists and philosophers have at all times devoted themselves to its dissection. The result of this is, that the anatomical history of the brain is one of the most perfect parts of anatomy. Very lately, this subject has been much elucidated by the publication of many new works, which have introduced some important improvements in this interesting part of the science.

The encephalon being of an extremely delicate texture, and its function being easily destroyed by the least derangement, nature has taken uncommon care to protect it from injuries arising from the contact of surrounding bodies.

Among the protecting parts of the brain, which have received the denomination *tutamina cerebri*, we remark the hair, the scalp, the muscles, the pericranium, the bones of the scull, and the dura mater, which are particularly destined to guard the cerebrum and cerebellum.

By its quantity and arrangement, the hair is very suitable to weaken the effects of blows upon the head. As it is a bad conductor of caloric, it forms a covering, the texture of which being loose, intercepts a large number of small masses of air; it is well disposed, therefore, to preserve the head of a uniform temperature, in some sort, independently of the air or surrounding bodies. As it is impregnated with an oily substance, it imbibes but a small quantity of water, and dries rapidly. The hair being also a bad conductor of the electric fluid, it in some degree insulates the head; hence the head is less likely to be affected by this agent.

It is easy to conceive how the scalp, the muscles which cover the cranium, and the pericranium, concur in protecting the brain; it will not be necessary, therefore, to insist on this point.

But of all the means of protecting the encephalon, the most efficient is the collection of bones, called the *cranium*, which completely envelop this organ. In consequence of the hardness and

strength of this envelope, and its spherical form, all pressure or percussion exerted upon any given part of the head is distributed from this point to all the rest, and is, therefore, less felt by the brain. If, for example, a man receives a blow from a cane on the top of his head, the motion will be propagated in every direction, and will extend even to the middle part of the base of the cranium, that is, even to the body of the sphenoid bone; if the blow be given upon the forehead, the motion will be propagated towards the middle of the occipital bone. In this transmission of motion through the bones of the cranium, it has been supposed that these bones experienced a slight, but reciprocal displacement, which were with difficulty distinguished, in consequence of the disposition of the different articulations. There are, however, good reasons to believe that the cranium resists as if it were a single bone.

Authors have not dwelt sufficiently upon the fact, that it must necessarily happen, that the cranium will change its form whenever it is pressed, or struck smartly. The softness of the cerebral mass will enable it to endure slight changes in the form of its envelope without any serious injury. The softer the brain is, the more able it will be to suffer strong pressure, or percussion, without inconvenience. This is the reason why newborn infants, in whom the bones of the cranium are very movable upon each other, often have the head strongly compressed, and even sensibly deformed, without any injurious consequences. The same things exist, in a degree, in children at a more advanced age, who receive, without danger, violent blows upon the head. In the early periods of life, the brain is much softer than in the adult.*

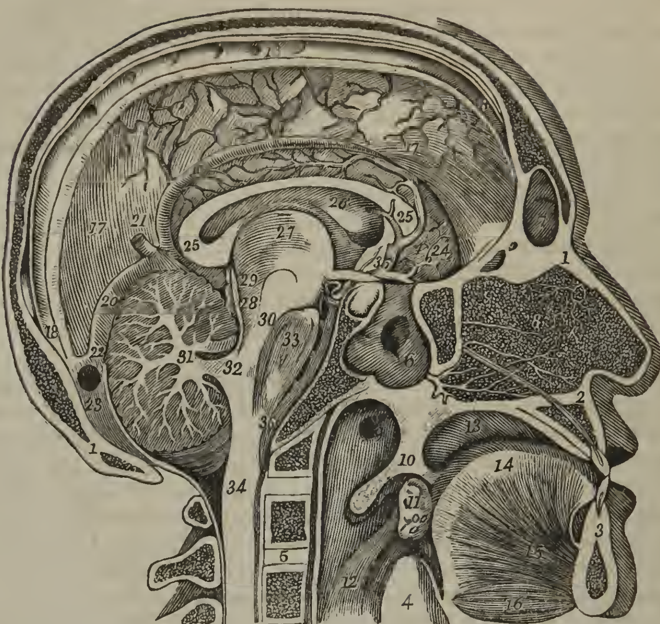
The dura mater is so arranged as to protect the brain, as it were, against itself. Indeed, without the folds which are formed by this membrane, viz., the falciform process and the tentorium, one hemisphere of the cerebrum would press upon the other when the head was inclined to one side, and the brain would compress the cerebellum when the head was erect; so that the different parts of the organ would destroy each other.

[The figure on the following page represents a longitudinal section of the head by Magendie; in which we see the encephalon, palate, tongue, falx, and pituitary membrane that lines the nasal passages.

1, 1, 1, 1. Longitudinal section of the cranium. 2, 3. Section of the superior and inferior maxillary bones. 4. Epiglottis. 5, 5. Section of the vertebral column. 6. Sphenoidal sinus. 7. Frontal sinus. 8. The septum narium lined with the pituitary membrane. 9. The internal orifice of the Eustachian tube. 10. A section of the veil of the palate and uvula. 11. The amygdalæ or tonsils. 12. Portion of the pharynx. 13. The palatine arch. 14. Section of the tongue. 15. Genio-glossus muscle. 16. Genio-hy-

* If the brain were perfectly fluid and homogeneous, whatever might be the changes in the form of its envelope, there would not result any injurious effects. But, as the brain is of a soft consistence, and not homogeneous, it follows that violent blows are often followed by serious consequences, such as concussion, extravasation of blood, abscess, &c.

(Fig. 20.)

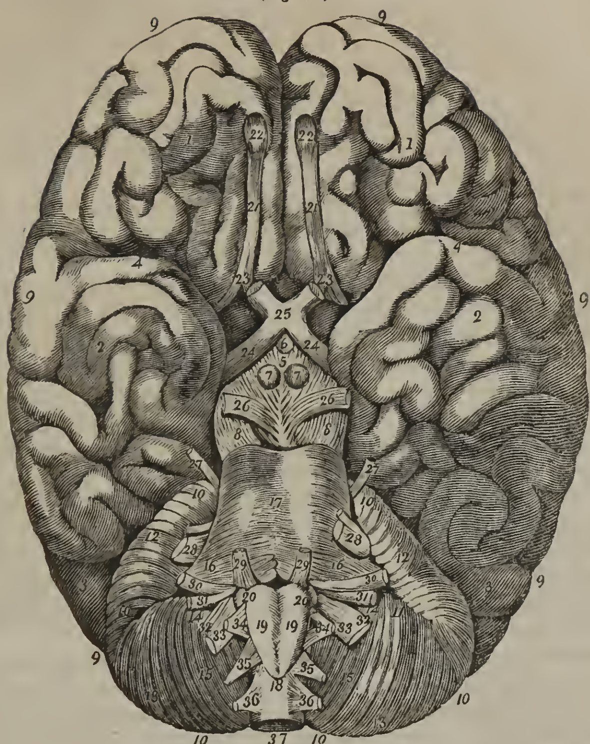


oideal muscle. 17. Falx cerebri. 18, 18, 18. Superior longitudinal sinus. 19. Inferior longitudinal sinus. 20. Right sinus. 21. The vein of Galen divided. 22. Confluence of the sinuses, opened. 23. Falx cerebelli. 24, 24. Internal face of the right hemisphere of the cerebrum. 25, 25. Section of the corpus callosum. 26. Right lateral ventricle. 27. Right thalamus nervi optici. 28. Tuberculæ quadrigeminæ. 29. Pineal gland. 30. Section of the peduncles of the brain. 31. Section of the cerebellum, arbor-vitæ. 32. Section of the peduncles of the cerebellum. 33. Section of the cerebral protuberance, or pons varolii. 34. Section of the medulla spinalis. 35. Right anterior cerebral artery. 36. The vertebral artery of the same side. 37. Naso-palatine nerve. 38. Internal branches of the left olfactory nerve. 39, 39. Branches of the spheno-palatine artery distributed to the septum and pituitary membrane.

The following figure represents the base of the encephalon deprived of its membranes and the encephalic nerves.

1, 1. Anterior lobes. 2. Middle lobes. 3. Posterior lobes; they constitute the base of the cerebral hemispheres, 9, 9, 9. 4. Fissure of Silvius. 5. Tuber cinnereum. 6. Infundibulum. 7, 7. Mammillary tubercles. 8, 8. Anterior peduncles of the cerebrum. 10, 10, 10. Circumference of the inferior surface of the hemispheres of the cerebellum. 12, 12. Anterior lobes of the cerebellum. 13, 13. Lobules of the medulla oblongata. 14. Lobules of the nervus vagus. 15, 15. Lobules of the medulla oblongata. 16, 16.

(Fig. 21.)



Peduncles of the cerebellum. 17. Pons varolii. 18. Medulla spinalis. 19, 19. Pyramidal eminences. 20, 20. Corpora olivaria. 21, 21. Olfactory nerves. 22, 22. Bulbs of these nerves. 23, 23. Roots of these nerves. 24, 24. Optic nerves. 25. Junction of the optic nerves. 26, 26. Common occular motor nerves. 27, 27. Pathetic nerves. 28, 28. Trigemini nerves. 29, 29. External occulor motor nerves. 30, 30. Facial nerves. 31, 31. Acoustic nerves. 32, 32. Glosso-pharyngeal nerves. 33, 33. Pneumo-gastric nerves. 34, 34. Hypo-glossal nerves. 35, 36. Vertebral nerves. 37. Section of the medulla spinalis.]

If we compare the precautions taken by nature to preserve the cerebrum and cerebellum from external injury, with those which we find she has guarded the spinal marrow, we shall be led to infer that this last is even of greater importance than the first; or that its texture, being more delicate, requires extreme care. This is, in fact, the case. The spinal marrow holds a rank in the animal economy at least as important as the cephalic portion of the nervous system. The least shock wounds it, the least compression destroys its functions in a moment. It was therefore necessary that the vertebral canal, which contains it, should afford a powerful protection. This end is attained in a manner so perfect, that

nothing is more rare than an injury of the spinal marrow. The vertebral column necessarily unites great solidity with great mobility. It is the centre of motion in all the efforts of the body; it is also the centre of motion in the action of the extremities, and executes very extensive movements itself.

We cannot here enter into the details of this admirable mechanism. We refer the reader to the "Anatomie Descriptive de Bichat," for a farther account of this subject.

But I have recently discovered an arrangement unknown to Bichat, which contributes powerfully to preserve the integrity of the spine.

The canal formed by the dura mater around the medulla spinalis, and which is lined by the arachnoid, is much larger than is necessary to contain this organ. Thus, in the dead body there is an empty space between the medulla and its membranous envelopes. I have named this space the *sub-arachnoidean cavity*. But during life, this space is filled by a serous fluid which distends the membrane, and which is projected several inches when a small puncture is made in the dura mater. There exists an analogous arrangement about the cerebrum and cerebellum, which do not fill exactly the cranium. I have given to this fluid the name *cephalo-rachidian*, or *cephalo-spinal*. It is not difficult to perceive that this fluid, which surrounds, and, as it were, suspends the medulla spinalis, somewhat like the fœtus in utero, must afford this organ efficient protection.

Besides the different envelopes of the brain, of which we have spoken, and the dura mater, which encloses it in its whole extent, this organ is surrounded by a very delicate serous membrane, which is called the *arachnoides*, the principal use of which is to form a very thin fluid, which lubricates the brain. The arachnoides penetrates into all the cavities of the brain, and forms there a perspiratory fluid.

The manner that the bloodvessels enter and pass out from the brain is extremely curious. We shall enter more particularly into a consideration of this subject when we come to treat of the circulation. We shall only remark here, that the arteries, before penetrating into the substance of this organ, are reduced to capillary vessels, and that the veins affect the same disposition in passing out from this substance. As these very fine blood-vessels communicate with each other by numerous anastomoses, the result is, that there is formed on the surface of the brain a vascular network, which has, very improperly, been called the *pia mater*. This network is introduced into the cavities of the brain, and it is this which forms the *plexus choroides*.

We shall not pretend to give here a description of the anatomy of the brain, but shall limit ourselves to some general reflections on the subject. Almost all authors, who have given an anatomical description of the brain in their works, have neglected to observe a proper strictness in the expressions employed, and have suffered their minds to be influenced by preconceived and

hypothetical opinions. It is indispensable for the future progress of anatomy and physiology, that we should employ terms which are precise, to avoid, as much as possible, hypothetical expressions, and, above all, to reject the supposition that the nerves terminate or unite at any given point of the brain; that the soul has its seat in any particular part of this organ; or that the nervous fluid is secreted by a certain portion of the cerebral mass, while the rest serves as a conductor of this fluid, &c. From neglecting this method, those authors who have described the brain have presented false ideas, expressed in an obscure manner.

When we speak of the encephalon, we mean the organ that fills the cavity of the cranium, and the vertebral canal. To facilitate the study of it, anatomists have divided it into three parts, viz., the *cerebrum*, the *cerebellum*, and *medulla spinalis*. This, however, is purely a scholastic distinction; in fact, these three parts form but one organ. The spinal marrow is no more a prolongation of the cerebrum and cerebellum than these are an expansion of the spinal marrow.

The brain in man presents great complications of structure and numerous distinct parts, which are not found in any other animal, as the corpora mammillaria and olivaria. Others are seen in many animals, but we are ignorant of their uses; as, the *corpus callosum*, *septum lucidum*, *cornu ammonis*, the *anterior* and *posterior commissure*, the *pineal gland*, the *pituitary gland*, and the *infundibulum*. All these parts no doubt execute important functions, but so defective has been the method of studying the cerebral functions that we are quite ignorant of them. There are some other parts of the brain the uses of which are beginning to be unveiled by experiment; the corpora striata, the thalami nervorum opticorum, the tubercula quadrigemina, the pons varolii, the pyramidalia and their prolongation beyond the corpora striata, the peduncles of the cerebellum, the hemispheres of these organs, and the different fasciculi which form the medulla oblongata and medulla spinalis.

In man, the encephalon is more voluminous than in other animals. The dimensions of this organ are proportioned to those of the head. Individuals differ very much in this respect. Generally speaking, the volume of the brain is in a direct proportion to the capacity of the mind. It would be incorrect, however, to suppose that every man who has a large head must necessarily be possessed of a superior intellect, because many causes, besides the volume of the brain, may increase the size of the head. But it is, nevertheless, very rare that a man distinguished for his mental faculties is not found to have a large head. The only means of ascertaining the volume of the brain in man, during life, is to measure the dimensions of the cranium. No other method, not even that proposed by Camper, can be relied upon.

The cerebrum of man presents more numerous circumvolutions, and deeper inequalities, than other animals. The number, volume, and arrangement of the circumvolutions are various. In

some brains, they are very large, and in others they are numerous and small. Their disposition differs in each individual. Those of the right side are not arranged like those of the left. It would be an interesting point to determine whether there exists any relation between the number of the circumvolutions and the perfection or imperfection of the intellectual faculties; between the modifications of the mind, and the disposition of the individual, and the arrangement of the cerebral circumvolutions.

The hemispheres of the human brain are distinguished by a posterior lobe, which covers the cerebellum.

The general form of the lobes of the brain vary in individuals, and perhaps also according to the intellectual capacity. In the brain of one of the most learned and illustrious individuals who have honoured France, they were nearly hemispherical.

The volume and weight of the cerebellum differ in different individuals, and at different periods of life. In the adult, the cerebellum is equal to the eighth or ninth part of the cerebrum; but it forms only the sixteenth or eighteenth part in newborn infants. We do not find circumvolutions on the surface of the cerebellum, but it is divided into lamellæ, each being separated by a furrow. The number and arrangement of these lamellæ differ in different individuals. We may here repeat the observation which was made above, in speaking of the cerebral circumvolutions. An Italian anatomist, Malacarne, is said to have found but three hundred and twenty-four of these lamellæ in the cerebellum of an idiot, while, in other individuals, he found more than eight hundred. I have opened the heads of a great number of persons labouring under mental alienation of various kinds, but without the same result.

In the depth of the cerebral substance, there are cavities which, from a remote period have been known by the name of ventricles. Of these cavities, one belongs to the cerebellum and medulla spinalis, and is the fourth ventricle; another is situated between the cerebral lobes, and is the third ventricle; lastly, in each of the hemispheres there is a much more spacious cavity than the preceding; these are the lateral ventricles. These different cavities communicate freely together; the third ventricle with the lateral ventricles by means of the two rounded openings called the holes of Monroe. A canal, known as the aqueduct of Silvius, unites the third and fourth ventricles. Lastly, the fourth ventricle communicates by an opening discovered by me some years since, which, variable in its extent and configuration, is always placed over the median line opposite to the calamus scriptorius, and opens into the sub-arachnoidean cavity, and is, consequently, immediately connected with the cephalo-rachidian fluid. By this opening, this fluid penetrates into the cavities of the brain, and, in certain cases, accumulates in considerable quantities. The mechanism by which the fluid enters into the ventricles and passes out by this opening will be described in its place.

The substance of the cerebrum is soft and pulpy; its form is

easily altered; in the fœtus, it is almost fluid; it has more consistence in childhood, and still more in the adult. We find, also, that the degree of consistence varies at different points of the organ, and in different individuals; the odour is insipid, and resembles that of the semen, and remains for many years in dried brains.

We find two substances in the brain. The one is gray and the other white. The first is called the *cineritious*, and the other the *medullary* substance. The *medullary* portion constitutes the greater part of the organ; it occupies more particularly the interior of it, and that part which corresponds to the base of the cranium. It has a fibrous appearance, and possesses more firmness than the cineritious part; and it forms a great part of the spinal marrow, particularly near its surface.

The *cineritious* substance, which is sometimes called cortical, forms a lamina varying in thickness on the external part of the cerebrum and cerebellum; and is likewise found in some of the internal parts. In some parts, it is covered by medullary matter, in others it seems intimately combined with it, and sometimes these two substances are disposed in laminæ or alternate striæ. We find other parts in the brain distinguished by their colour, viz., yellow, black, &c.*

To say that the cineritious substance of the brain produces the white part is entirely gratuitous. Indeed, the cineritious no more produces the white part of the brain than a muscle produces the tendon in which it terminates, or the heart the aorta. In this respect, the anatomical system of Messrs. Gall and Spurzheim is unfounded. Besides, generally, the white matter is formed before the gray, and many white parts have no connexion with the gray.

When we examine the cerebral substance by means of a microscope, it appears to be formed of an immense number of globules, of unequal magnitude; they are said to be about eight times smaller than those of the blood. In the medullary substance, they are disposed in right lines, and have the appearance of fibres; in the cineritious substance, they seem to be thrown confusedly together.

According to M. Vauquelin, there is no difference in the chemical composition of the different parts of the nervous system. The analysis of the cerebrum, cerebellum, spinal marrow, and nerves, exhibit the same results.

He found them composed of

Water	80.00
White fatty matter	4.53
Red fatty matter	0.70
Osmazome	1.12
Albumen	7.00
Phosphorus	1.50

Sulphur and salts, such as

* Sœmmering distinguishes four substances in the brain, viz., white, gray, yellow, and black.

Acid phosphate of potash " " lime " " magnesia	} . .	5.15

The arteries of the brain are large, and are four in number, viz., the two internal carotids, and the two vertebrals; they have a peculiar arrangement, on which we shall more particularly insist under the article *arterial circulation.* We shall only observe here, that they are principally placed at the inferior part of the organ; that, by their anastomoses, they form a circle, and that they are reduced down to capillary vessels before they penetrate into the substance of the brain. It has been computed that the brain receives about one eighth of all the blood which passes from the heart. But this estimate is only an approximation, the quantity varying, no doubt, according to a great variety of circumstances. We know, from recent dissections, that the cerebral arteries are accompanied by filaments of the great sympathetic nerve; we can trace these filaments with ease along the principal branches of the arteries. It is to be presumed, therefore, that they accompany them even in their most minute ramifications. But it is not to be concluded, necessarily, from this disposition, which is common to all the arteries, that the brain receives nerves. The filaments of the great sympathetic have here, as they have everywhere else, an evident connexion with the parietes of the arteries.

The cerebral veins have also a peculiar arrangement. They occupy the superior parts of the organ, they have no valvular structure, and they terminate in canals, situated between the laminæ of the dura mater. We shall particularly investigate this subject under the head *venous circulation.* No lymphatic vessels have yet been detected in the brain.

Observations made on the Brain of Man and living Animals.

It has been ascertained from the heads of newborn infants, the cranium of which is still membranous, and from those of adults, where the brain has been denuded by wounds and disease, that it has two distinct movements. The first is evidently synchronous with the pulsation of the heart and arteries; the second, with respiration; that is, the organ seems to sink down upon itself at the moment inspiration takes place; the opposite phenomenon occurs during expiration. According as the respiration is more or less strong, are these motions of the brain manifest. These two motions are very readily remarked in animals; it is not easy to explain why the existence of this phenomenon should lately have been called in question. It is thought that these motions are very slight when the integrity of the cranium is preserved, and that they are necessary to the perfection of the cerebral functions; but this is a point which has not been demonstrated.

The cerebrum, cerebellum, and medulla spinalis, surrounded by the cephalo-spinal fluid, fill exactly the membranes which surround them; they exercise even a certain pressure upon their

surface. This pressure arises from the force with which the blood penetrates the parenchyma, from which it must result that the cerebral substance, incapable of effort itself, is incessantly pressed between the blood and the resistance offered by the membranous and osseous envelopes. As the force of the blood varies, according to a number of circumstances, the pressure that the brain must undergo must vary in the same proportion.

It appears that this pressure is indispensable to the functions of the organ. If it be suddenly diminished or augmented, the functions are suspended. If the diminution or increase is made gradually, the cerebral functions remain. One of the most simple means of diminishing this pressure is to make a puncture behind the occipital bone, between it and the first vertebra. The cephalo-spinal fluid will generally escape in the form of a jet, and immediately the cerebral functions will be evidently disturbed. I have, however, seen animals from which I have removed this fluid continue to live without any very apparent derangement of the nervous functions.

Examined in a living animal, the brain presents some remarkable properties very different from what might be imagined. Who would suppose, for example, that the greater part of the hemispheres, if not all, is insensible to pricking, tearing, cutting, and even cauterization? And yet, of this fact, experiment leaves no doubt. Who would think that an animal could live for several days, and even weeks, after the hemispheres had been entirely removed? But many physiologists, ourselves among the number, have witnessed this in different classes of animals. But what is less known and more surprising is, that removing the hemispheres in certain animals, as the reptiles, produces so little change in their usual gait, that it is difficult to distinguish them from sound animals.

Lesions upon the surface of the cerebellum show, also, that this organ is not sensible; but deeper wounds, especially those which affect the peduncles, are attended with effects of which we shall speak hereafter.

But this does not hold true with respect to the spinal marrow; the sensibility of this part of the encephalon is exquisite, with this remarkable circumstance, that it is greatest at the posterior part, much less on the anterior part, and almost destitute of sensibility about the centre of the organ. It is from the posterior part that the nerves arise which are destined to bestow general sensibility.

The sensibility is also very vivid on the sides and interior of the fourth ventricle; but this property diminishes as we approach the anterior portion of the medulla spinalis. It is very weak in the tubercula quadrigemina of the mammiferi. We shall speak hereafter of the brain as connected with motion.

The uses of the brain in the economy are extremely important and numerous. It is the organ of intelligence; it is the source of all those means by which we act upon external bodies; it exercises an influence, more or less marked, upon all the phenomena

of life, and it establishes a relation, always active, between the different organs; or, in other words, it is the principal agent of the sympathies. We shall now consider it under the first character.

Of the Understanding.

Whatever may be the number and diversity of the phenomena which pertain to the human understanding, however different they may appear from the other phenomena of life, and though they may be evidently dependant upon the soul, it is indispensable to consider them as the result of the action of the brain, and not to distinguish them, in any way, from other phenomena, which are dependant on organic action. Indeed, the functions of the brain are absolutely governed by the same general laws as the other functions; they are developed, and they decay, with the progress of age; they are modified by habit, sex, temperament, and individual character; they are deranged, depressed, and exalted by disease, and the physical lesions of the brain prevent or destroy them. In a word, like every other organic action, they are not susceptible of explanation by us, and in investigating them, laying aside hypothesis, we must be governed by observation and experience alone. It is also necessary to guard ourselves against the impression that the study of the functions of the brain is more difficult than that of the other organs, and that it belongs exclusively to metaphysics. By adhering rigorously to observation, and scrupulously avoiding all explanations or conjectures, this study becomes purely physiological. Perhaps it is even easier than many of the other faculties, from the facility with which we are enabled to produce and examine its phenomena, inasmuch as we have only to turn our attention upon ourselves, to *listen* or *think*, so that the phenomena may be subjected to our observation.

But this constitutes one of the great difficulties of the subject. That spirit which turns its activity upon itself, which forces itself to know itself, is doubtless a wonderful attribute of man. We owe to this gift many of the advantages we possess. But we find here one obstacle to our insatiable love of knowledge: we cannot overcome certain unsatisfactory notions respecting the phenomena which pass in our own understandings. That which occurs in the brains of others is equally beyond our reach, and becomes strongly an object of our conjecture; we cannot comprehend faculties which we do not possess, or, at least, have but very imperfect notions of them.

This incapacity of knowing that which is not in us, is as true as regards metaphysicians and philosophers as of common men. Whatever desire they may have to describe and class the intellectual faculties, they have not succeeded; for it is not sufficient to announce what has passed in the mind of an individual, but it is necessary to give a general view of what takes place in all. But who would flatter himself that he comprehended precisely the understanding even of the individual who is dearest to him,

and with whom he is the most intimately allied? who is quite certain that he knows himself? Are we not often surprised at the sudden development of faculties that we did not suspect? Who, then, can undertake, with reasonable hopes of success, to trace the history of the human understanding?

But however this may be, the study of the understanding has not heretofore been considered as constituting an essential part of physiology. One science is specially devoted to this, and is called *ideology.* Persons desirous of examining this interesting subject *in extenso,* may consult the works of Bacon, Locke, Condillac, Cabanis, and, especially, the excellent work of M. Destutt Tracy, entitled "Elements of Ideology." We shall confine ourselves to some of the fundamental principles of this science.

The innumerable phenomena which constitute the human understanding* are but modifications of the faculty of perception. When we examine them with attention, we shall find no difficulty in confirming this observation, the truth of which is generally admitted by modern metaphysicians.

We may divide the faculty of perception into four principal modifications:

1st. Sensibility, by which we receive impressions from within or from without. 2d. Memory, or the faculty of reproducing impressions or sensations previously received. 3d. The faculty of perceiving the relation between sensations or judgment. 4th. Desire or will.

Of Sensibility.

All that we have said of sensations, generally, will apply to sensibility: for this reason, we shall here limit ourselves to observing, that this faculty is exerted in two very different modes. In the first, the sensation passes unobserved by us; we do not perceive it. In the second we take notice of it, and are conscious of its existence. It is not sufficient, then, that a body acts upon our senses, or that the nerve transmits the impression which it has received to the brain; it is not even sufficient that this organ receives this impression. In order for a perfect sensation to exist, it is necessary that the brain should perceive the impression received by it. An impression thus perceived is called, in ideology, a *perception,* or *idea.*

We may easily prove upon ourselves the existence of these two modes of sensibility. It is easy to see, for example, that a crowd of objects are continually acting upon our senses, without our noticing them. This effect depends in a great measure upon habit.

Sensibility varies, infinitely, in different individuals. In some, it is very obtuse; in others, it exists in an extraordinary degree; generally, in those who are well constituted, there is a medium between these two extremes.

* The human understanding has been called the spirit, the faculties of the soul, intellectual faculties, cerebral functions, &c.

In infancy and youth, the sensibility is vivid, and remains nearly in the same state until the adult age; but as old age advances, it becomes materially diminished, so that the decrepit are nearly insensible to all the causes of ordinary sensations.

It may be asked, with what part of the nervous system the sensibility is most particularly connected. We can now reply, with some precision, to this important question. Already, we have pointed out the class of nerves which, especially, concur in this phenomenon. They are the posterior roots of the compound nerves, and the superior branch of the fifth pair. I have shown, by experiment, that if these nerves are divided, the sensibility of the parts to which they are distributed is extinguished. Experiment has equally informed me, that if we divide the posterior fasciculi of the spinal cord, the general sensibility of the trunk is abolished. With respect to that of the head, and more particularly of the face, and its cavities, I have shown that it depends on the fifth pair. If this nerve be divided before it passes out of the cranium, all the sensibility of the face is lost. The same thing takes place if the trunk of the nerve is cut at the side of the fourth ventricle.

Lastly, it is necessary to descend below the level of the first cervical vertebra, that a lateral section of the spinal cord should not be followed by the loss of general sensibility of the face, together with that of the senses. As the origin of the fifth pair approaches near the posterior fasciculi of the spinal cord, which appear to be the principal organs of the sensibility of the trunk, it is probable that there is a continuity between these cords and the fifth pair. But this fact is not demonstrated, either by anatomy or physiological experiments.

The principal seat of general sensibility and of the senses is not situated either in the cerebrum or cerebellum. I have given what I regard a satisfactory demonstration of this. Remove the lobes of the cerebrum and cerebellum in one of the mammiferous animals, and then endeavour to satisfy yourself if it is capable of sensations, and you will readily find that it is sensible to strong odours, tastes, and sounds. Thus, it is evident that the sensations are not seated in the lobes of either the cerebrum or cerebellum. I have not cited vision in the above enumeration of the senses. It appears, from the experiments of Rolando and Flourens, that vision is abolished by the abstraction of the cerebral lobes. If the right lobe be removed, the vision is lost in the left eye, and *vice versa.*

The reader may depend upon the truth of this fact, as I doubted for some time its exactitude myself, and was, therefore, induced to verify it by repeating it several times. A wound of the thalamus nervi optici is followed by a loss of vision in the opposite eye. I have not found that a wound of the optic tubercle, or anterior quadrigemina, altered vision in the mammiferi; but it is very apparent in birds. In the latter, the abstraction of the hemispheres renders the eye insensible to the most vivid light. Thus,

there are a number of the different parts of the nervous system necessary to vision; for the exercise of this sense, the integrity of the hemispheres, the optic thalami, perhaps, of the anterior tubercula quadrigemina, and of the fifth pair are indispensable. We may remark that the influence of the hemispheres and of the optic thalami is crossed, while that of the fifth pair is direct.

If we inquire why the sense of vision differs so much from the other senses, as respects the number and importance of the nervous parts which concur in it, we shall find that vision rarely consists in a simple impression of light; that this impression may even take place without the existence of vision; that, on the contrary, the action of the optic apparatus is generally connected with an intellectual or instinctive effort, by which we determine the distance, size, form, and motion of bodies; an effort which probably requires the intervention of some of the most important parts of the nervous system, and particularly of the cerebral hemispheres.

Of the Memory.

The brain is capable, not only of receiving impressions, but also of reproducing those which had before existed. This cerebral action, when it produces recently-acquired ideas, is called *memory.* It is called *recollection* when the ideas have been long acquired. An old man who recalls the events of his youth, *recollects them;* a man who retraces the sensations which he has experienced during the past year, *remembers them.*

Reminiscence is an idea reproduced, which we do not recollect to have previously received.

Like sensibility, the memory is very much developed in infancy and youth. At this period of life, the mind acquires knowledge with the most facility, especially of that kind which does not require much reflection; such as languages, history, and the descriptive sciences. In the progress of age, the memory becomes weakened; it diminishes in the adult, and is almost lost in old age. We sometimes see individuals, however, whose memory remains even at the most advanced periods of life. This advantage is, generally, derived from constant exercise, as has been sometimes observed in actors. But it is, undoubtedly, true, that it often exists to the injury of the other intellectual faculties. The more vivid the sensations are, the more easily are they remembered. The memory of internal sensations are almost always confused. Certain diseases of the brain completely destroy the memory.

The memory exercises itself in an exclusive manner, if I may be allowed the expression, on different subjects. There is a memory of words, of places, of forms, of music, &c. It is rare that an individual unites these different memories; they are generally isolated, and almost always form a striking trait of the understanding, of which they constitute a part. Diseases sometimes present psychological analyses of the memory; one patient may lose the

memory of proper names, another of substances, a third of numbers, and cannot count above three or four; or he may lose the memory of language, and the faculty of expressing himself on any subject. Generally, in these cases, after death, lesions are found to a greater or less extent in the brain or medulla oblongata. But morbid anatomy has not established a direct and constant relation between the diseased part and the kind of memory abolished, so that we are still ignorant if there exists any part of the brain which is more particularly destined to the exercise of memory.*

Of Judgment.

There can be no doubt that judgment is the most important of the intellectual faculties. It is by this faculty that we acquire all our knowledge. Without it, our life would be purely vegetative, and we should have no idea of the existence of other bodies, or even of our own, as all our knowledge is the direct result of the faculty of judgment. To form a judgment is to establish a relation between any two ideas, or collections of ideas. When I judge that a work is good, I perceive that the idea of goodness agrees with the book which I have read; I establish a relation, I form an idea different from what sensibility or memory would have enabled me to form. A series of judgments connected together constitute reasoning. We may readily conceive how important it is for us to form correct judgments, that is, that we do not establish any relations but those which really exist. If I judge a substance which is poisonous to be salutary, I incur the danger of losing my life; the false judgment which I have formed will be very injurious to me. The same remark will apply to all false judgments. Nearly all the misfortunes to which man is exposed, morally speaking, have their origin in errors of judgment; crime, vices, and bad conduct, are all the results of false judgments.

It is the object of one science, viz., logic, to teach us to reason justly. But sound judgment and good sense, or erroneous judgment and mental weakness, are the results of organization. It is impossible to change in this respect; we must remain as nature has formed us. Some men are endowed with the valuable gift

* Phrenology, a *pseudo-science* of the present day; like astrology, necromancy, and alchemy of former times, it pretends to localize in the brain the different kinds of memory. But its efforts are mere assertions, which will not bear examination for an instant. Craniologists, with Dr. Gall at their head, go even farther: they aspire to nothing less than determining the intellectual capacities by the conformation of the crania, and particularly by the local projections which they remark. A great mathematician presents a particular elevation about the orbit; this is said to be the organ of calculation. A celebrated artist has a large bump on the forehead; that is the seat of his talent. But, replies some one, Have you examined many heads of men who have not these capacities? Are you sure that you do not meet with the same projections, the same bumps? That is of no consequence, replies the craniologist; if the bump is found, the talent exists, only it is not developed. But here is a great geometrician, or a great musician, who has not your bump. No matter, replies the sectary, you must believe. But, replies the skeptic, the aptitude should always exist, united with the conformation, otherwise it will be difficult to prove that it is not a mere coincidence, and that the talent of the man depends really on the particular form of his cranium. Still, replies the phrenologist, believe! And those who delight in the vague and the marvellous, do believe. There is some show of reason in this, for they thus amuse themselves, while the truth would only cause them ennui.

of discovering relations which have never before been perceived by others. If these relations should happen to be important, so as to confer great benefit on mankind, their possessors are said to be men of genius; but if they relate to objects of less importance, they are said to possess wit, or imagination. It is principally by their manner of perceiving relations, or judging, that men differ from each other. Vivacity of sensation appears to be injurious to correct judgment; this is the reason why this faculty becomes more perfect with age.

We are ignorant of the part of the brain which is the particular seat of judgment. It has been long believed to be in the hemispheres, but nothing directly proves this.

Of the Desire, or Will.

We give the name of will to that modification of the faculty of perception by which we experience desires. In general, it is the consequence of our judgment, and it is worthy of remark, that upon this faculty our happiness or unhappiness necessarily depends. When our desires are satisfied, we are happy; we are unhappy, on the contrary, when we cannot gratify them. It becomes us, therefore, so to direct our desires that we shall be enabled to gratify them. We must avoid desiring, for example, those things which it is impossible for us to obtain; and it is still more important for us not to desire those which are injurious, for in this case we cannot escape unhappiness, whether we indulge them or not. Morality is a science, the object of which is to give the best possible direction to our desires. Desires have been generally confounded with that cerebral action which presides over the contraction of the voluntary muscles. I think it advantageous to the student that this distinction should be established.

Such are the four principal distinctions into which the faculty of perception has been divided; they have been called the *simple faculties of the mind.* It is the combination and reaction of these faculties upon each other which constitutes the understanding of man and the higher order of animals. There is, however, this remarkable difference between man and other animals: they remain always in nearly the same state, their faculties receiving but little improvement in the course of their lives; but man derives improvement from every object by which he is surrounded, and is thus enabled to attain that intellectual superiority by which he is distinguished.

The faculty of generalizing, which consists in creating signs to represent ideas, to assist thought by means of these signs, and to form abstract ideas, is characteristic of the human understanding. It is this which enables it to acquire that prodigious extension which we see in civilized nations. The faculty of generalizing can, of course, only exist in a state of society. An individual who should have lived alone, and who should not have had any intercourse with his fellow-creatures, even in his early years, of which there have been several examples, would not differ much from

brute animals; he would only possess the four simple faculties of the mind. It is the same with those individuals to whom nature, by a defective organization, has denied the faculty of employing signs, or of forming these abstract or general ideas; they remain all their lives in a perfect state of brutality, as we observe in idiots.

In general, the physical circumstances in which a man finds himself placed will have a powerful influence upon the development of his understanding. If he is enabled to procure subsistence with ease, and to satisfy all his physical wants, he will be in a situation favourable to the cultivation of his mind and a free development of his mental faculties; but if he can only, with difficulty, satisfy the demands of nature, his mind, being chiefly directed to that single point, will necessarily remain in a rude and imperfect state, as is always found to be the case among savages and slaves.

The intelligence of man is limited by the number of his faculties, and the degree of development of each. No one can pass beyond the point allotted to him by his organization. It is in vain that he endeavours to acquire those aptitudes which nature has not granted to him. But each one, by exercising the faculties that he does possess, may extend them, and carry them to a degree of perfection far beyond that at which they would have remained if they had not been frequently exercised. This is the important end to which education should be directed.

Certain philosophers, or, rather, dreamers, have supposed that all men are born with equal intellectual capacity, and that education, and the circumstances in which they may have accidentally been placed, determine the differences that we observe; but nothing can be more erroneous than this supposition. From the idiot, who is incapable of eating without assistance, like an infant at the breast, to the man of genius, whose discoveries ameliorate the social condition, there are an infinite variety of shades, which constitute the individual lot of humanity. One man possesses all his faculties, but in a *minimum* degree; another has many eminent faculties, while he is inferior or incapable as it respects the others; a third has but one faculty, if I may be allowed thus to express myself, while the others are so defective that he appears to be destitute of them; lastly, there are privileged men, in whom nature has combined, in a high degree, all the capacities of the human mind. These men, so happily constituted, enjoy immense advantages unknown to the rest of mankind. They may, for example, comprehend everything, and make themselves understood by all, which is not permitted by common intelligences. These *complete men* are rare.

What is true of men, taken individually, without distinction of race, holds true also as respects the varieties of the human species. The descriptions of travellers and historians have enabled us to form a sort of scale of intellectual capacity, from the Caucasian variety, to which we belong, to the ferocious and brutal savage

of the Southern islands, who has never raised himself above the use of his canoe. The different states of civilization, observed among the numerous races of men scattered over the surface of the earth, may thus be considered, not merely accidental shades, the consequences of manners, customs, and climates, but the immediate and necessary results of organization.

It might appear necessary next to enumerate and describe, successively, the different faculties of the human understanding; but I have already explained, above, the reasons why this attempt has been heretofore confined to the most distinguished metaphysicians. It would, therefore, be most rash for us to undertake an object so difficult, and, perhaps, impossible to accomplish.

Man acquires his ideas and knowledge of the objects which surround him by means of his senses and intelligence; this constitutes his learning or acquirements, the extent of which varies according to his aptitudes and the exercise they have received, that is, his *experience.* It depends upon ourselves, with the faculties with which we are endowed, to acquire more or less knowledge, and to augment thus the intensity of our existence and the chances of our happiness; for, generally speaking, men's happiness increases with their intelligence. Unhappiness, on the contrary, for the most part, originates in ignorance.

There are many things over which our minds have no control, but which, nevertheless, deeply interest us. Urged on by that admirable faculty by which we are prompted to seek for causes, we often imagine we have succeeded, when everything shows the importance of our efforts; or we admit that which has been imagined by others possessed of bolder and more fertile spirits. Thus are formed hypotheses, systems, doctrines, creeds, which divide, with learning, the attention of men, and which often engross the best minds.

Thus the sum of ideas that our intelligence procures us is composed of that which is *real*, or which *we know*, and that which we believe, or imagine, or have admitted without proof; in other words, *that of which we are ignorant.* Thus, to believe, or to create a system or doctrine, is, rigorously speaking, but to be ignorant. I am far from pretending that all that we believe is necessarily false or merely imaginary. Undoubtedly that which we believe may be true and real, but it only acquires this character to us when it is capable of being verified by experimental proofs.

In this respect, mankind may be divided into two classes, which are destined always to remain distinct from each other. The object of one is positive, experimental truth; the other is satisfied with that which is vague, fanciful, wonderful, perhaps even absurd. They attach more importance, and feel deeper interest, as their belief is their own peculiar work, adapting itself perfectly to their minds—making, in some sort, a part of themselves; they maintain it with warmth, energy, extreme tenacity; it is impossible to demonstrate to them that they are in error.

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These two classes of minds have shown themselves, though with different results, in all those pursuits connected with the intelligence of man. The first have founded and perfected the sciences, and all positive human knowledge; the second have shone, with a brilliant light, in the arts of imagination: that career is their peculiar domain. But, unfortunately, it has often happened that those who possess the latter class of minds have also cultivated natural philosophy; but so far from promoting its progress here, as in other instances, ideas are made to supply the place of facts; the offspring of their imaginations become the great phenomena of nature. Dangerous energy! barren zeal! which tend to annihilate these very sciences, and to erect in their place fantastic images, which vanish before the first examination of a positive mind, the friend of reality.

Of Instinct.

Nature has not abandoned animals to themselves. It is necessary that each should exercise a series of actions, from which results that astonishing harmony which we witness among organized beings. To induce animals to concur in this, and to execute those actions for which each is designed, nature has given them *instinct;* that is, desires, inclinations, wants, by means of which they are continually and forcibly compelled to fulfil the designs of nature.

Instinct may exist in two different ways, viz., with or without a knowledge of the end. The first may be called *intelligent instinct;* the second, *blind*, or *brutal instinct.* The first is more particularly the prerogative of man; the second pertains to animals.

In examining, with care, the numerous phenomena which depend upon instinct, we find that it has two principal objects; the first is the preservation of the individual, and the second that of the species. There are as many instincts as species of animals, varying according to their organization. As organization varies among individuals, these instincts are much more remarkable in some than others.

In man, we find two kinds of instincts: the first relates to his condition as an animal, and is always exhibited by him in whatever situation he is found. This kind of instinct resembles that of animals. The other arises from the social state. Without doubt it depends, like every other vital phenomenon, upon organization. But this is never developed but in a state of civil society; for this purpose, it is necessary that he should enjoy those advantages which accompany this state.

The first, which may be called animal instinct, includes hunger, thirst, a want of clothing, and habitation; a desire of happiness, or of agreeable sensations, and the fear of pain and death; a disposition to destroy other animals, or even those of his own species, when dangers are to be feared from them, or advantages to be derived from their destruction; the venereal appetite; attachment to children; tendency to imitation; and a love of soci-

ety, which leads to civilization, &c. These instinctive sentiments are constantly acting upon man, and induce him to concur in the order established among organized beings. The natural wants of man are more numerous and various than those of other animals, in a direct proportion to his intelligence. In every other respect he enjoys a decided superiority over all other animals.

When man lives in a state of society, he is enabled easily to satisfy all the wants of which we have been speaking; he has then *leisure;* in other words, to satisfy these first wants, requires but a small portion of his time and faculties. Then arise new wants, which may be called *social.* Such is our desire to have a very vivid consciousness of our existence; a feeling which, the more it is indulged in, the more difficult it is to satisfy, because, as we have already observed, our sensations become weakened by habit.

This fondness for vivid impressions, joined to a continual diminution in the strength of our sensations, causes inquietude and vague desires, which are increased by the importunate recollection of the vivid sensations that we formerly experienced. For the purpose of removing this state, we are compelled to have recourse to a continual change of objects, or to increase the intensity of the same sort of impressions. From this arises an inconstancy, which does not permit us to fix any limits to our wishes, and a progression of desires which are annihilated by indulgence, but afford us no gratification; hence arises *ennui,* that unceasing source of misery to civilized man when he has no employment.

This desire of vivid sensations is counterbalanced by a love of repose, or indolence, which acts so powerfully on the higher classes of society. These two opposite sentiments modify each other, and from their action and reaction result a love of power, of consideration, and of wealth, which enables us to indulge both. These two instinctive sentiments are not the only ones which arise from the social state; it develops a crowd of others, less important, indeed, but not less real. Our natural wants, also, become remarkably altered; instead of hunger, a most capricious taste is often substituted; for the venereal desire, feelings of a very different nature, &c. Natural, modify social wants, and *vice versa;* and when, in addition to this, we recollect that age, sex, temperament, &c., have a strong influence upon all our desires, we may form some idea of the difficulties which a study of the instinct of man presents. This part of physiology has been heretofore scarcely noticed.

We may at the same time remark, that an increase of the social wants is always accompanied by a corresponding development of the understanding. There is no comparison, as relates to the capacity of the mind, between man in the more opulent class of society, and as he is found in that condition where all the physical energies are barely sufficient to provide for his first wants. The innate dispositions or instincts particularly occupy the phrenologists at the present time. Their efforts are especially

directed towards the triple end of recognising and classifying the instinctive dispositions, and assigning the distinct organs in the brain. But it must be admitted that thus far there is little appearance of success.

Of the Passions.

In general, we understand by the term passion an extreme and exclusive instinctive sentiment. A man in a passion neither sees, hears, nor is conscious of anything but the sentiment by which he is excited; and as the violence of this sentiment renders it disagreeable, and even painful, it has received the name of passion or suffering. Passions have the same end as instincts; they induce animals to act according to the general laws of living bodies.

We see in man passions, which he has in common with other animals, which consist in vehement animal desires; and others which display themselves in a state of society only; these are the social wants very much increased.

The animal passions relate to a double end, as we have before remarked, in speaking of natural instinct, viz., the preservation of the individual and that of the species.

To the preservation of the individual, belong fear, anger, grief, hatred, and excessive hunger, &c.; to that of the species, the venereal appetite, jealousy, and furious anger, when the offspring is in danger. Nature has attached great importance to this class of passions, which exist in their full force in man in a state of society.

The passions peculiar to a state of society are but the social wants carried to an extreme degree. Ambition is but the excess of a love of power; avarice, an excessive desire of fortune; hatred and vengeance are but natural and impetuous wishes to injure those who have injured us; a passion for play, and almost every other vice, are the results of a love of violent excitement; violent love is but an exaltation of venereal desires, which agitate, pervert, and often animate us with ineffable pleasure, &c.

Among the passions, some weaken or extinguish themselves when they are satisfied; others, again, increase by indulgence. Happiness is often produced by the first, as we sometimes see in love and philanthropy; but unhappiness is necessarily attached to the last, examples of which are constantly furnished by the ambitious, avaricious, and envious.

If wants develop the powers of the understanding, the passions are the principal cause of everything very great which has been accomplished by man. The great poets, heroes, criminals, and conquerors have always been men who were strongly under the influence of the passions.

In speaking of the passions, shall we say, with Bichat, that they reside in the organic life, or, with the ancients and some moderns, that anger is in the head, courage in the heart, and fear in the semilunar ganglion, &c.? Passions are but internal sensations;

they cannot, therefore, be said to have a seat; they result from the action of the nervous system, particularly of the brain; they do not, therefore, admit of explanation. We are capable of observing, directing, calming, or extinguishing, but not of explaining them.

CHAPTER X.

OFFICES OF THE CEREBRUM AND CEREBELLUM.

[Intellection is the most remarkable office of the encephalon. Thought, perhaps, is not necessary to the existence of animals, though some degree of it seems implied in all endued with the power of voluntary motion. In the lowest orders of animals no distinct encephalon exists; but, as we rise in the scale, we find these organs bestowed. They are at first in a simple form, but gradually attain their highest development in the vertebrated animals. The large nervous masses constituting the encephalon are, no doubt, the centres of the nervous system and the seat of intellection, the cerebrum appearing to be more particularly appropriated to this latter office. It does not necessarily follow that the power of an organ should always increase with its size, as in some instances the organ more than makes up for its want of size by the energy of its vital actions. These, however, are but exceptions, it being a general law of the animal economy that the size and development of an organ are indicative of its relative power. Agreeably to this rule, the most cursory observation shows that generally a striking relation does exist between the volume and form of the encephalon, and the manifestations of intellection, in different animals.

The mass of the encephalon, in proportion to that of the rest of the body, is, generally speaking, greater in man than in other animals, though there are exceptions. It is also generally, though not, perhaps, invariably, true that the encephalon in him is larger, in proportion to the other parts of the nervous system, than in other animals. The nerves, the immediate instruments of the senses, by which ideas of surrounding objects are collected, are larger and more developed in other animals; but the encephalon, the organ of intellection, in which ideas derived by means of the senses appear to be combined, and, as it were, wrought up into thought by reflection, is relatively much more ample in man. It is also generally, if not invariably, true, that the degree of intelligence in animals is indicated by the development of the cerebrum, especially the anterior lobes. It is on this postulate that craniology rests.

The facial angle of Camper is liable to the obvious objection that it only pretends to make us acquainted with the capacity of

the cranium from its anterior to its posterior part, but takes no notice of its lateral expansion. Still, it is admitted to be a general index of the intellectual power, not only of different animals, but of the different varieties of the human race, and even individuals.

Dr. Gall and his followers have gone a step farther, and alleged that the cerebrum consists of a collection of organs, and, according to their development, form corresponding cranial prominences; so that, by examining the cranium, an experienced observer can determine not only the degree of intellection, but the mental peculiarities and propensities of an individual. The first aspect of these doctrines is certainly extravagant and visionary, and, as has been complained even by some who have adopted them, have been carried to an extreme. Still, there has been a spirit of inquiry awakened, and the subject has been pursued with an enthusiasm by some gifted minds, among whom may be named Dr. Caldwell, of Kentucky, which has thrown light upon the physiology and pathology of the nervous system, and is deserving of some farther notice. One of the circumstances that has tended particularly to give currency to these doctrines is the isolated character of several of the intellectual faculties. Some of them are separable from each other by clearly-defined lines in the normal state, and are sometimes modified or abolished by disease, while the other faculties are scarcely disturbed. We may mention the loss of the memory of words as one of the most striking examples of this. The organ of speech is stated by Spurzheim to be situated in the anterior lobes of the cerebrum. Now it has been alleged, that, in fatal cases of apoplexy attended with this sympton, loss of memory of words, appreciable organic lesion of the anterior lobes is generally found. Bouillaud states that four cases where this coincidence occurred came under his own observation. He farther remarks, that, on a careful examination of the numerous cases of cerebral affections collected by Lallemand and Rostan, he found thirteen similar cases. Such, he states, was the uniformity of this coincidence, that, after reading the symptoms of a case, from the presence or absence of it, he could pronounce with accuracy whether lesion of the anterior lobes had or had not been found.

After making this statement, Bouillaud exclaims, with his characteristic enthusiasm, "How can this truth be hereafter contested, inasmuch as it is thus established by direct observation; *first*, that speech was disordered or completely destroyed when the anterior lobes were affected; *second*, that speech continued when the lesion was situated in other parts of the cerebrum?"* But farther inquiry has shown the necessity of greater caution in such generalizations. Remarkable as these facts appear, farther inquiry has proved that they were mere accidental coincidences. Thus, a case has since been related by Cruveilhier where the anterior lobes were entirely wanting, in a case of congenital malformation, in which the patient had been idiotical from birth, and in

* Bouillaud, d'Encephalite, p. 168.

whom almost the only indication of intellect was the power of articulation.* Numerous cases have also since been observed in which the anterior lobes were disorganized without loss of speech, and the reverse. In thirty-seven cases of cerebral hemorrhage of one of the anterior lobes, observed by Andral, twenty-one were accompanied by loss of speech, while in sixteen it was preserved; in seven, where the hemorrhage was confined to the posterior lobes, speech was abolished in all; and in seven others, where it was confined to the middle lobes, there was also loss of speech in all.†

It has been observed, also, that comparative anatomy is opposed to the doctrines of the phrenologists. It is a curious circumstance that the difference in the antero-posterior diameter between the brain of man and that of the lower mammalia principally arises from the shortness of the posterior lobes in the latter, these being seldom long enough to cover the cerebellum; yet it is in these posterior lobes that the animal propensities are regarded by phrenologists as having their seat. On the other hand, the anterior lobes, in which the intellectual faculties are considered as residing, in many animals bear a much larger proportion to the whole bulk of the brain than they do in man.‡

Another of the fundamental assumptions of craniology is, that the ossific textures have no independent power of development, but are moulded to the forms of the soft parts. Hence, as is alleged, the irregularities on the inner surface of the cranium, and those external prominences which mark the localities of the organs. But there are reasons for believing that the cranium possesses an inherent power of development, and that the irregularities of its surfaces referred to are attributable to this power, and not to their being moulded to the form of the brain. The case of Cruveilhier, above referred to, may be cited in proof of this. The subject, a female, died at the age of fifteen, having been idiotical from birth. The external appearance of the cranium was natural; but, on removing it, the anterior lobes of the cerebrum were altogether wanting, their place being occupied by a gelatinous fluid; yet the inner surface of the cranium presented irregularities similar to other skulls. But though phrenology is by no means without objections, yet it is admitted to be an ingenious and plausible hypothesis, and to have found able defenders and ardent admirers among some gifted members of the profession.

But other inquiries have been instituted for the purpose of determining the portion of the brain in which intellection is performed, without pretending to ascertain the exact seat of each faculty or desire with the particularity affected by Dr. Gall and his followers. Among those who have investigated this subject with the most ability and zeal, and whose facilities for observation were the best, may be mentioned Foville, Pinel, Grand Champs, and Bouillaud. All these distinguished pathologists have agreed

* Cruveilhier, Anat. Path., liv. viii.

† Andral, Pathol. Interne, t. iii, p. 98.

‡ Carpenter.

in the opinion, derived from observing the effects of disease, that the whole of the cortical substance of the hemispheres, and especially the anterior lobes of the cerebrum, are the parts in which intellection is more particularly executed. This was not so broadly advocated by Sir Charles Bell, though it would appear that he leaned to this view.

An opinion has long been entertained by physiologists, that the number and size of the convolutions of the brain, and especially the depths of the furrows between them, are indicative of the intellectual power of the individual. Malacarne had noticed that the convolutions in the brains of idiots are smaller in size, fewer in number, and the anfractuosities less strongly marked than in other persons. The comparative intelligence of the inferior animals is remarked to be much more accurately indicated by the convolutions of the brain than the capacity of the cranial cavity. Their intelligence is also alleged to diminish in proportion to the decrease in the gray or cortical substance of the brain. In the fœtus the gray substance is scarcely found, but increases as the intellectual powers are developed; while in old age it is said to diminish with the fading powers of the mind. The suggestion, therefore, that this portion of the cerebrum is more particularly the seat of intellection, seems a natural corollary from these premises.

The experiments of Flourens, some of which are very remarkable, have had great influence in giving confidence to the opinion that the periphery of the cerebrum is more particularly the seat of intellection. Of a great number of experiments, represented as being attended with similar results, we shall refer here but to one. "He removed the two cerebral lobes of a hen, at the same time carefully avoiding those inferior portions of the lobes connected with the roots of the olfactory nerves. The bird was immediately deprived of vision and hearing, and fell into a stupor. It remained in this state, merely taking a little water, which was poured down its throat, until the third day, when it began to revive, and was ultimately restored to good health. But it appeared to be perfectly unconscious of everything that took place about it. It appeared entirely destitute of taste, smell, vision, or hearing. It never made any effort to eat or drink. It could walk, but if it met any object it did not appear to know how either to avoid or go away from it. It digested the food that was forced down, and even grew fat. Though apparently destitute of intelligence, the locomotive powers of this animal were completely preserved. It could walk, run, and fly. It survived this loss of its cerebral lobes six months, and then was killed. Though deprived of its senses, its organs of sense appeared perfect. The eye was as clear and natural in appearance, and the iris preserved its motion as before."

But if the surface of the cerebrum, and particularly its anterior lobes, be the seat of intellection, we should naturally expect that an inflammation, or other morbid state of these parts, would necessarily be followed in every case by disorder of this function.

Still, it is universally admitted that this does not by any means uniformly occur. Where the lesion is confined to one hemisphere, this has been plausibly, if not satisfactorily, explained by the symmetrical character of the encephalon. It has been said, like the eyes, or the ears, or other symmetrical organs, that when one side of the encephalon was affected, the office of intellection might be executed by the other. The wisdom and benevolence of this arrangement have been eloquently dwelt upon by Bouillaud. We shall not deny that each half of the encephalon is capable, like the other symmetrical organs, of acting, to a certain extent, independently. We may remark, however, that the analogy is not complete.

But admitting this explanation to be sufficient where the pathological condition is confined to one hemisphere, if we consider the cerebrum as the seat of intellection, how shall we account for the uninterrupted execution of this function where considerable organic lesion of the greater part of the periphery of the cerebrum and of its anterior lobes exists? This is no doubt a rare event, yet it undoubtedly sometimes occurs. The following interesting case is related by Dr. Boerstler, of Lancaster, Pennsylvania, in an excellent letter addressed by him to Professor Dunglison, published in the first number of the "Medical Library and Intelligencer," edited by the latter gentleman. The whole case, including the treatment, is published at length. We have only extracted those parts which have a direct bearing on our present inquiry. It is strikingly opposed to the views of Bouillaud and others, that "when the two hemispheres are profoundly altered, the intellectual and moral faculties are abolished, and sensation and voluntary motion paralyzed, the patients resembling those animals in which the lobes had been removed."*

"The patient was a lad about eleven years of age, who, in consequence of a kick from a newly-shod horse, had the superior portion of the os frontis and the anterior portion of the right parietal bone fractured. One portion, an inch and a half long, was driven into the anterior lobe of the cerebrum to the depth of an inch, in removing which a tablespoonful of brain was discharged. There was great laceration of the meninges, from the ragged edges of the bony fragment. The integument was lacerated and bruised, and sloughed in a few days, leaving a considerable portion of the scull and cerebrum exposed."

There was some intellectual confusion at first, but "*at the end of two hours he recovered every faculty of the mind, and they continued vigorous for six weeks, and to within one hour of his death, which took place on the forty-third day.* During all this period there was little apparent derangement in any of the organs, except a slight irritative fever, which supervened sixteen days after the injury, and continued to the termination of the case. So slight, however, was the indisposition, that the patient sat up every day, and frequently walked to the window to see the boys play in

* Bouillaud, d'Encephalite, p. 266–7.

the street, in which he took a deep interest, frequently laughing at their gambols."

"Four hours after death the body was examined by Dr. Boerstler, in the presence of Drs. Ohr, Edwards, and Newcomer. Upon removing the cranium, the dura mater presented strong marks of inflammation over the entire arch of the head, being deeply injected in some parts, and having depositions of coagulable lymph in others. The dura mater was ulcerated at three points. The space previously occupied by the right, anterior, and middle lobes of the cerebrum presented a *perfect cavity*, the hollow of which was filled with sero-purulent matter, the lobes having been destroyed by suppuration, and the third lobe much disorganized. The left hemisphere was in a state of *ramollissement* down to the corpus callosum. It was so much softened that the slightest touch would remove portions, and with the aid of a sponge I wiped away its substance near to the corpus callosum, when it became firmer, but presented the appearance more of a homogeneous mass than of regular organization. The chiasm of the optic nerves, as well as their entire tract, was so soft as to yield to a slight touch with the handle of the scalpel, and the olfactory nerves were in the same condition. The corpus callosum, thalami nervorum opticorum, and tubercula quadrigemina were in a physiological state. The cerebellum presented no pathological condition; the spinal column was not examined."

"This boy was remarkably intelligent. In my daily visits I held frequent conversations with him, and in all my observations I could not discover the slightest derangement of his intellectual faculties; no dulness of sensibility, no obtuseness of perception, no impairment of judgment, no want of memory, and, so far as mind was concerned, he gave no evidence of disease. His vision, audition, and voice were unimpaired."

This well-authenticated case is of itself sufficient to unsettle our confidence in all those speculations respecting the functions of the superficial and superior portions of the cerebrum, especially the anterior lobes, which have been so generally received. It seems to show that these parts are far from being exclusively the seat of intellection and indispensable to the offices of the organs of the senses, as was alleged by Flourens. The anterior and middle lobes of the *right side* were completely destroyed, and the third much disorganized, yet, contrary to the almost universal experience and opinions of modern physiologists, there was no appreciable alteration in the senses or power of voluntary motion in the opposite side. The lobes of the *left hemisphere* were not so absolutely destroyed, yet the disorganization was such as would lead us to expect abolition of their functions. It is evident, however, that we have much to learn respecting the effects of softening of the textures, especially the cerebral, in weakening or abolishing the functions of a part. This kind of disorganization has only within a few years excited the attention of pathologists. The mode in which *ramollissement* of the encephalon arises, and

the precise nature of this pathological condition, are by no means satisfactorily ascertained. Sometimes it appears to arise from inflammation, but at others it does not. It has been compared to gangrene, but the history of this case seems opposed to such an opinion. The autopsic examination was made so early after death as to remove every reasonable doubt as to its having existed during life, and probably for a considerable time. Other cases, though perhaps no one so conclusively, have shown that *ramollissement* of the encephalon may exist without abolition of function. The state of the chiasm of the optic nerves and of the olfactory nerves proves this beyond doubt.

A vast number of experiments were made by Rolando, Serres, Le Gallois, Flourens, Desmoulins, and Magendie, on living animals, for the purpose of determining precisely the functions of the different portions of the encephalon. Their experiments were generally ingeniously designed, skilfully executed, and in some instances the results were curious and interesting. One of the most remarkable circumstances is the great restorative power of the animal economy in overcoming extensive mutilations of these most important organs. But when they are carefully analyzed, they do not throw as much light on the objects of their investigation as might have been anticipated, and very little on the seat of intellection in the human subject. There are some grave objections to this mode of investigation; the pain that must be necessarily inflicted, and the disorder induced in all the functions consequent upon these sufferings, must essentially influence the results; while the great difference which manifestly exists between the functions of these organs in man and the inferior animals, allows little weight to any inferences that may be drawn with respect to the former. The results of these experimental inquiries are also different, and in some points opposed to each other; and while they prove how unsatisfactory this mode of investigation is, they also show the difficulty of the subject, and how little we at present understand it.

Nor are the results of our inquiries on this subject derived from pathalogical anatomy much more satisfactory. The causes of obscurity are different, but perhaps as great. Lesions resembling each other in locality and extent are attended with widely different symptoms; while in some cases apparently a change of structure limited in extent and trifling in degree, is attended with the most alarming and fatal consequences; in others the most extensive disorganizations may continue for years, without scarcely disturbing the harmony of the functions. A case is mentioned by Dr. Abercrombie of a female who, from the history of the case, had been evidently labouring under a chronic affection of this kind for four years, yet the functions of intellection, sensation, and voluntary motion were not essentially disordered. Similar observations have been made as respects chronic hydrocephalus; the ventricles have been found so distended that the cerebral matter has seemed like a thin lamina, spread over the interior of the crani-

um. It is very remarkable that sudden injuries of this organ, even though slight, are often followed by the most violent symptoms; while in chronic diseases extensive changes of structure may occur with but trifling external indications. But if any definite portion of the cerebrum be exclusively concerned in intellection, we should naturally expect to find indications of it on examining the bodies of those who have died after having suffered long from mental alienation. Until very recently, however, it has not been pretended that any uniformity in the cadaveric appearances could be traced in this disease. Morgagni, the most accurate of the older pathological anatomists, acknowledges that he could find nothing uniform or characteristic of mental alienation, while Pinel and Esquirol expressly declare that pathological anatomy of the brain threw but little light upon the disease. In 259 dissections of maniacs, made under the supervision of Messrs. Esquirol, Villemain, Beauvais, and Schwilgæ, only 68 were found to exhibit any appreciable indications of lesion of the brain.* M. Esquirol seems to have attached more importance to the form, thickness, density, &c., of the cranium than to any other pathological appearance about the heads of maniacs.

More recently, however, Foville, Calmeil, and Falret, have endeavoured to show that certain appreciable changes of structure do occur with great uniformity in the encephalon of maniacs. M. Foville has especially described certain changes in the structure of the cortical substance, which he thinks may be traced with great regularity in this class of patients. One of the most uniform of these appearances is an induration of the surface of the brain, in consequence of which, this thickened and hardened portion of the cortical part may be detached like a thick, dense membrane. He says that an obvious difference in density is observable between the cortical substance thus detached and that underneath, which may be recognised by scraping them with a scalpel. He alleges, though he had frequently made examinations of persons dying of other diseases, that he had never observed this appearance, but that he had noticed something similar in the brains of a hyena and a badger, both of which died in a state of captivity.

He also alleges that he had found combined with this hardening of the superficial lamina of the cortical substance of the brain various modifications in its colour and appearance, while the form and size of the convolutions had undergone a marked change; their upper part in many cases appearing to have fallen into a state of atrophy, which gave to them an appearance as if they had been pinched up between the fingers in some instances; in others, the loss of substance was about their base; while again, in some cases, scarcely any vestiges of the convolutions remained. In these cases of atrophy, the gray substance was generally more firm than natural, while in many instances it had become so pale, that he found it difficult to distinguish the limits be-

* See Med. Chir. Rev., v. x., and Borrowe on Insanity.

tween the cineritious and medullary portions. In some cases, however, the cortical substance was softened instead of being hardened. Some alterations are also mentioned by M. Foville as having been observed in the colour and density of the medullary portions of the brain and the meninges.

With respect to these observations, we may remark, that at present they may be considered as proper subjects of inquiry, not as points in pathological anatomy that are already established. That some of these and other morbid appearances are sometimes found in various parts of the brains of maniacs, there can be no doubt; the question is as to their uniformity. Though M. Foville and others think they have discovered certain appearances which occur with great regularity, yet they are at issue on this point with some of the highest authorities in the profession.

There is but one other condition of this organ to which we shall at present refer to elucidate this question—the precise seat of intellection. It is to those cases which we occasionally meet, where certain parts of the cerebrum have not become developed, or have fallen into a state of atrophy. We have already referred to one case of this kind by Cruveilhier, in which there was a congenital deficiency of the anterior lobes, accompanied with idiocy and inability of progression. Breschet has recorded three cases where there was this defect in the organization: one was blind, but possessed sensation, and the power of voluntary motion; and one was idiotical, and destitute of vision and olfaction. In another case, the posterior lobes were deficient, and the person idiotical. Cases are also referred to by Andral (*Pathol. Intern.*, t. iii., p. 114) of atrophy of the corpus callosum and pineal gland, the latter diminished to the size of a millet seed, the rest of the encephalon being in a normal state, also accompanied by idiocy. Thus it appears that defective development, or atrophy, not only of the anterior lobes, but various other parts of the brain, may be accompanied by idiocy. Nothing positive can be inferred from these facts, therefore, as to the seat of intellection.

From what has been said, we are led to infer that intellection is chiefly executed by the cerebrum, although, as will be hereafter seen, there is reason for thinking that some acts, that may be properly referred to this head, are dependant upon the cerebellum. It is quite certain, at least, that these organs are intimately associated in function as well as structure. From the premises, it would also appear that, in the present state of our knowledge, there is no sufficient evidence that intellection is exclusively executed by any one part of the cerebrum, but probably that all are auxiliary to, and concur in, this great end.

Besides intellection, there are two other classes of vital phenomena to which we have referred as being connected with the encephalon, viz., voluntary motion and sensation. The former of these has been supposed to be ultimately referrible to the cerebrum, and the latter to the cerebellum. But this may be more satisfactorily shown in investigating the functions of the medulla

spinalis and cerebro-spinal nerves. Another feature in the structure and functions of the encephalon, which has been already alluded to, and which it is indispensable to keep in mind in our physiological and pathological investigations, is the symmetrical character of these organs. Like the other double organs, as we have seen, each half appears to possess, to a certain degree, an independent power of action. They are, however, peculiar in this, that the influence of each hemisphere, instead of extending to the corresponding side of the body, is chiefly confined to the opposite side. The advantages of this arrangement are not obvious, though incontrovertibly established. Hence, it happens that lesion of one side of the encephalon is accompanied by impaired sensation or voluntary motion, or both, on the opposite side. This is, however, generally, not invariably true, sometimes the paralysis corresponding to the side of the encephalon where the lesion exists.

The offices of the cerebellum have not been ascertained with much precision. One of these functions which has of late excited considerable attention, but of which our knowledge is at present loose and indefinite, is the supposed influence exercised by it over the generative functions. There are sound analogical reasonings and pathological facts which appear to furnish support to this doctrine, to which it will now be proper to refer. In the first place, it has been remarked by phrenologists, by which we mean the followers of Gall, that the development of that part of the cranium in which the cerebellum is contained, and, of course, the organ itself, indicates, with great uniformity, the erotic disposition of the individual. It is undoubtedly true, that a great expansion of this part of the cranium, accompanied, as it usually is, with corresponding thickness of the neck, tends to give a gross and sensual expression to the individual. It is also frequently true, that persons of this conformation are generally distinguished for their robust constitution, and, perhaps, for their inclination to venereal indulgence, though the latter may be a consequence of the former. The effects of emasculation upon the development of this part of the cranium and neck, in the inferior animals, particularly the horse and bull, have also been referred to as furnishing strong proofs of the intimate connexion existing between the cerebellum and the generative organs. The cerebellum rapidly increases from childhood with advancing age, its magnitude, in proportion to the rest of the encephalon, being double at puberty that of the infant. It has also been frequently remarked, that pain in this part often follows excessive indulgence of this passion ; while in the female it is often complained of during menstruation.

There have been a number of remarkable cases related by Serres, Larrey, Andral, and others, of persons dying with symptoms of excitement of the generative organs, satyriasis, nymphomania, priapism, &c., &c., in whom there was found after death marks of inflammation, or hemorrhage, in the cerebellum, particularly the middle lobe. Some remarkable cases are also rela-

ted of wounds of the occiput having been followed by loss of the venereal appetite, and atrophy of the generative organs.

Serres has related a number of curious facts of this kind that fell under his observation. In one instance a man was seized with apoplexy during coition. Priapism continued until the approach of death. On examination, there was found hemorrhagic effusion into the substance of the cerebellum at a great number of different points. In another person who had died apoplectic, in whom also priapism constituted a symptom which continued until the approach of death, indications of inflammation, and erosion of the middle lobe of the cerebellum, were found; and a large coagulum of blood effused into the right lobe of the organ, which had forced its way into the fourth ventricle. This man had several apoplectic paroxysms in the two days which preceded his death, during each of which there was a tense erection of the penis, and in the last an abundant discharge of semen. In a third case, attended with symptoms of satyriasis, ejaculation of the semen, and tumefaction of all the generative organs, there were found indications of inflammation in both the right and left lobes of the cerebellum, and gangrenous effusion at a number of points in the middle lobe. In a body brought to him from the hospital of the Bicêtre, in which there was great tumefaction of the penis and scrotum, he found extensive inflammation of the cerebellum. A girl who had given herself up to the most licentious habits, and who died with violent symptoms of nymphomania, exhibited marks of chronic inflammation and induration of the middle lobe of the cerebellum.* Baron Larrey, in his *Clinique Chirurgicale*, has recorded also a number of cases having a similar bearing. In some, where shrinking of the occiput occurred, apparently as a consequence of emasculation; and others, where injuries of the cerebellum were alleged to have been followed by atrophy and loss of function of the genital organs. One of the most remarkable of these cases is that of a soldier, who was wounded in the back of the head, but got well. When the baron saw him, three months afterward, he states that he was so changed that he did not know him. He had become beardless, and his voice was feminine. On examination, he found the genital organs in a state of atrophy, reduced to the size of those of an infant. Some have undertaken to doubt the accuracy of these last statements, though we are not aware of its having been done on sufficient authority.

But cases similar to those which we have thus related have been described by some of the highest and most recent authorities in the profession. Andral, in his late excellent work, the *Pathologie Interne*, has related several interesting cases corroborative of this reciprocal influence supposed to exist between the cerebellum and genital organs, though he is far from giving an unqualified assent to this doctrine. Pains of the occiput are common, not only during menstruation, but also frequently arises as a conse-

* V. Begin, &c.

quence of disordered menstruation. But this, as we shall see hereafter, does not necessarily arise from irritation of the cerebellum, but sometimes from spinal irritation. M. Andral speaks of a young man who came under his care, who suffered excruciating pain in the occiput always after coition. Another had suffered for a considerable time from frequent painful priapism, during which he had an acute pain in the occiput. One day M. Andral was sent for in great haste to this last patient, and found him labouring under all the symptoms of acute meningitis, accompanied with furious delirium, of which he died. Unfortunately, no post mortem examination was made.

But when we deliberately examine the known facts on this subject, they by no means conclusively establish the doctrine that the cerebellum is exclusively, or even chiefly, appropriated to the generative functions. Comparative anatomy is for the most part opposed to it. The male frog is so excited during the season that it will endure the most extensive mutilations without relaxing its embrace of the female, yet its cerebellum is much smaller proportionally than some of the fishes, which have no direct sexual intercourse. One of the strongest arguments in favour of this doctrine is the apparent shrinking and assumed atrophy of the cerebellum in emasculated animals, particularly the stallion and bull. But the recent observations suggested by M. Levret, published in his Comparative Anatomy of the Nervous System, proves that these assumptions are entirely unsupported. The experiments were made by M. Lassaigne on ten stallions, of the ages of from 9 to 17; in twelve mares, of from 7 to 16 years; and twenty one geldings, from 7 to 17 years. The weight of the cerebellum, both absolute and as compared with that of the cerebrum, was adopted as the standard of comparison. The results of these observations were directly opposed to the statement of the phrenologists. They proved that the proportional size of the cerebellum in geldings was decidedly *greater*, instead of less, than either in entire horses or mares. The following is a comparative statement of the weights:

	Average.	Highest.	Lowest.
Stallions,	61	65	56
Mares,	61	66	58
Geldings,	70	76	64

These experiments go far to show that, instead of the cerebellum being reduced by castration, as asserted by Gall, the reverse is true, and that the cerebrum is more likely to have its comparative size diminished by this operation.

But if organic lesions of the cerebellum have in some instances been attended by disordered function of the genital organs, as has been now described, yet it must be acknowledged that this is far from being uniformly the case, nor is it by any means certain that they were not mere accidental coincidences. On the contrary, the greatest variety in the symptoms consequent upon acute and chronic inflammation, sanguineous effusion, and injuries of the cer-

ebellum, has been observed. In some cases, hemiplegia, in others, mere muscular weakness; again, in some the sensation is disordered or abolished, while the power of voluntary motion continues. Amaurosis has also been frequently observed to occur in children, where dissection has shown tubercles of the cerebellum. There is another circumstance which may be mentioned as having a bearing upon this point, the reciprocal influence of the cerebellum and genital organs. It is the change which takes place in the latter on the approach of old age. There is not only impaired function, but even atrophy of these organs, though no corresponding change occurs in the cerebellum. The cerebrum sometimes shrinks in old age, but it is remarked that this rarely, if ever, occurs in the cerebellum.

The following curious case tends still more strongly to create doubts on this point. It is a case related by Dr. Combette, of a girl who lived until she was eleven years of age, in whom the cerebellum was found in a state of atrophy. She was melancholy, of limited intelligence, but the other functions were natural.* This girl had been known for several years to indulge in masturbation. Andral states that he had been able to collect but twenty cases of tubercle of the cerebellum. Of this number there was but one, a case recorded by M. Montault, in which there were any remarkable symptoms connected with the generative organs. In him the venereal desire is represented to have been excessive.† What adds very much to the difficulty and obscurity of this subject is, that inflammation and congestions of the cerebellum are very often complicated with similar affections of the cerebrum. Thus it becomes extremely difficult to discriminate between the symptoms.

In the present state of our knowledge, then, it is doubtful how far the cerebellum exerts a peculiar influence over the functions of the genital organs. It is one of those vexed questions in which the judgment should be kept in abeyance until elucidated by farther inquiry.

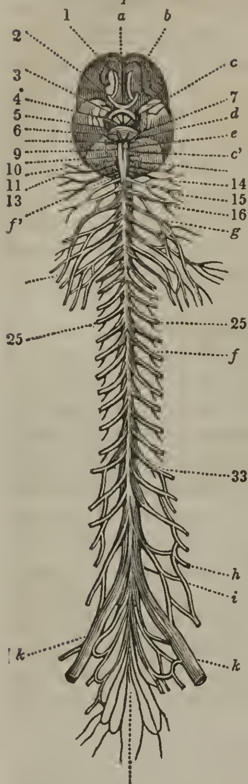
Medulla Spinalis.

The functions of the medulla spinalis are intimately connected with those of the cerebrum and cerebellum, yet, like them, its offices may in some degree be regarded as independent. Though great light has been thrown on the functions of the spinal chord, especially by the investigations of Sir Charles Bell, and M. Magendie, yet the precise offices of the central nervous masses are far from being clearly defined. The subject is complicated, and is still involved in much obscurity. To render it more intelligible to the student of physiology, we present in the following diagram a delineation of the whole of the cerebro-spinal axis, seen on its anterior surface, the nerves being divided at a short distance from their origin.

* V. Gazette des Hopitaux, 1831.

† Pathologie Interne.

(Fig. 22.)
Cerebro-Spinal Axis.



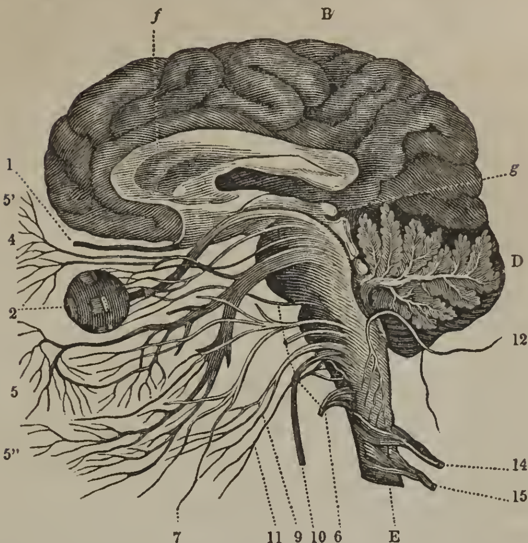
a. The brain. *b.* The anterior lobe of the left hemisphere. *c.* The middle lobe. *d.* The posterior lobe, nearly concealed by the cerebellum. *f.* Medulla oblongata. 1. Nerves of the first pair, or olfactory. 2. Second pair, or optic. 3. Nerves of the third pair, which originate behind the interlacing of the optic nerves in front of the pons varolii, and above the peduncles of the brain. 4. Nerves of the fourth pair. 5. Trifacial, or nerves of the fifth pair. 6. Nerves of the sixth pair, lying on the pons varolii. 7. Facial nerves, or nerves of the seventh pair; and acoustic, or nerves of the eighth pair. 9. Glosso-pharyngeal, or nerves of the ninth pair. 10. Pneumogastric, or nerves of the tenth pair. 11. Nerves of the eleventh and twelfth pairs. 13. Suboccipital, or nerves of the thirteenth pair. 14, 15, 16. Three first pairs of cervical nerves. *g.* Cervical nerves, forming the brachial plexus. 25. A pair of the dorsal nerves. 33. A pair of the lumbar nerves. *h.* Lumbar and sacral nerves, forming the plexus, from which arises the nerves of the lower extremities. *i* and *j.* Termination of the spinal marrow, called the cauda equina. *k k.* Great sciatic nerves going to the lower extremities.

The following diagram (Fig. 23) represents a vertical section of the cerebrum, cerebellum, and medulla oblongata, with the nerves which arise from the base of the brain and medulla oblongata, and their general distribution.

A. Anterior lobe of the cerebrum. B. Median lobe. C. Posterior lobe. D. Cerebellum. E. Spinal marrow. *f.* Section of the corpus callosum. *g.* The optic lobes. 1. Olfactory nerves. 2. The eye, in which terminates the optic nerve, the root to which may be followed on the sides of the annular protuberance to the optic lobes; behind, we see the nerve of the third pair. 4. Nerve of the fourth pair, which is distributed, like the preceding, to the muscles of the eye. 5. Superior maxillary branch of the fifth pair. 5. Opthalmic branch of the same pair. 5. Inferior maxillary branch of the same nerve. 6. Nerve of the sixth pair, going to the muscles of the eye. 7. Facial nerve. Below the origin of this nerve we see a section of the acoustic. 9. Glosso-pharyngeal, or nerve of the ninth pair. 10. Pneumogastric. 11. Hypoglossal, or nerve of the eleventh pair. 12. Spinal, or nerve of the twelfth pair. 14, 15, 16. Cervical nerves.

(Fig. 23.)

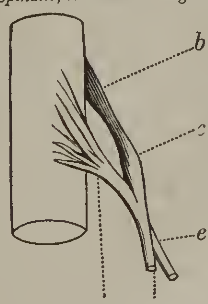
A Vertical Section of the Encephalon, from Milne Edwards.



The brain and medulla spinalis communicate through the medium of the medulla oblongata; hence the importance of a knowledge of this part physiologically. The thirty-one pairs of compound nerves, that arise from that portion of the spinal marrow contained in the vertebral canal, arise by double roots, presenting, near their origin, a ganglion.

(Fig. 24.)

A Section of the Medulla Spinalis, to show the Origin of the Compound Nerves.



a. Spinal marrow. *b.* Anterior root of one of the spinal nerves. *c.* A ganglion situated in the course of this root. *d.* The posterior root of the same nerve, united to the anterior root beyond the ganglion. *e.* The common trunk, formed by the union of these two roots. *f.* A small branch anastomosing with the great sympathetic nerve.

The medulla spinalis, when removed from its bony case, presents an outline which has been compared to a pillar, of which

the medulla oblongata is the capital, and which extends the whole length of the trunk. It is the first part of the encephalon developed in the fœtus, and the only portion of the brain indispensable to fœtal life and growth, as would appear from the fact that acephalous children, in whom all the parts of the cerebrum and cerebellum are wanting, except the medulla oblongata, are often well formed, and even robust at birth; yet they rarely survive for more than a few hours. We also sometimes meet with cases of chronic hydrocephalus, in which there is entire disorganization of the cerebrum and cerebellum, yet the child may support a sort of vegetative life for years. The importance of the medulla oblongata, as a part of the medulla spinalis, may be inferred, not only from its being always found in acephalous children, but also from the fact that if, in the turtle and some other cold-blooded animals very tenacious of life, the head be cut off, if the decollation be practised below the medulla oblongata, the body dies, and the head continues to live; but if above this part, it is the reverse. M. le Gallois also found that he could cut down the brain until he came to this part without interrupting the respiration; but if it was mutilated, this function ceased.

The medulla spinalis is a prolongation of the encephalon, arranged into such a form as to facilitate free and equal communication between the central nervous masses and the remote parts of the body, through the medium of the nerves. According to Sir Charles Bell, it consists of three distinct parts: the anterior fasciculi destined to voluntary motion, the posterior to sensation, and the middle to respiration. Its structure is fibrous, any interruption of the continuity of which is followed by a loss, or other lesion of sensation or voluntary motion, at or below that portion of the body at which the injury occurs.

Sensation and voluntary motion are the most widely-extended offices of the cerebro-spinal system. There are forty-three pairs of cerebro-spinal nerves; of these, thirty-one pairs are appropriated to common sensation and voluntary motion. The latter, with a single exception, viz., the trigeminus, arise with great regularity in pairs on each side of the medulla spinalis. They are called *compound nerves*, because they arise by double roots from the anterior and posterior fasciculi of the cord; they are then united in one sheath, and, as they retain the original properties of the portions of cord from which they are derived, they are each composed of a filament of sensation and voluntary motion. These compound nerves pass out at right angles from the medulla spinalis, and are distributed to the corresponding portions of the body; the upper cervical to the head and neck, the lower cervical and upper dorsal to the superior extremities and corresponding portions of the trunk, and the lower dorsal and lumbar to the inferior portions of the trunk and lower extremities. Another circumstance in the distribution of the compound nerves, exceedingly interesting in a pathological point of view, is their connexion with the great sympathetic nerve. These nerves, as they pass from

the medulla spinalis, run directly to communicate with the sympathetic, sending probably filaments to be distributed with it to the corresponding viscera and parts of the body. As the functions or properties of the compound nerves depend upon the medulla spinalis, any lesion of the medulla spinalis itself, or of the nervous filaments at any intermediate point between their origin and periphery, will impair or destroy their function. Thus, if injury of a filament of sensation going to one of the extremities occurs, the result may be increased, diminished, modified, or lost sensibility in the part, the power of voluntary motion, remaining unimpaired, and *vice versa*. The seat, nature, and extent of the lesion, whether it affect a single nervous filament, a considerable trunk, or the medulla spinalis itself, will determine the character of the morbid phenomena that will ensue. Thus there may be numbness, loss of sensation, formication, or neuralgic pain. If there be lesion of the filaments of motion, there will be spasms, convulsive twitchings, muscular weakness, or entire loss of the power of voluntary motion. These lesions of sensibility and voluntary motion may exist singly or together; they may affect a very limited space, as the tip of the finger, or extend to half the body, or all.

Sensation, which may be considered as including the sense of touch, is very widely diffused. It constitutes a most important sentinel in protecting the organization from various noxious influences to which it is exposed. Its distribution over the integument is indispensable to its preservation. We are thus admonished not only of injurious variations of temperature, but are also prevented from subjecting any part of this organ to long-continued pressure by remaining long in the same position. In lying, the pressure made by the prominences of the bones become disagreeable, and we change our posture. We see the importance of this admonition in those cases where there is loss of sensibility, paralytics being exceedingly liable to ulceration, and even gangrene of the skin, from this cause. Another striking example of this is alluded to by Sir Charles Bell. The cheek derives the power of sensation from the gangli*onic*, and of voluntary motion from the ganglion*less* portion of the trigeminus. In paralysis of the trigeminus, the tongue still retaining its power of voluntary motion, during mastication the food accumulates between the cheek and jaw of the paralyzed side, and has been known to remain in this state, without the consciousness of the patient, until putrefaction had taken place. Indeed, the presence and characters of disease are traced chiefly by means of disordered sensations and voluntary motions. In explaining these phenomena, we are, therefore, to keep in mind the origin, structure, functions, and distribution of the nerves of sensation and motion. In most pathological conditions, this is the only key to a just diagnosis and sound therapeutic treatment.

Thus we can understand how lesions of particular portions of the medulla spinalis, by modifying the functions of the compound

nerves which pass off at these points, are indicated by disordered sensibility, motion, or other function in the corresponding organs and parts of the body. We also thus see satisfactorily explained, how it often happens, that when there is a considerable lesion of a portion of the medulla spinalis, not only the functions of the corresponding parts of the body are affected, but also those parts which are situated below the point at which the lesion or disorganization exists. This is, however, a general, not universal law, there being some extraordinary exceptions recorded of the reverse. M. Velpeau has described some remarkable instances of this. In one case, a young man died, at the age of eighteen years, after protracted sufferings arising from an injury of the occiput. To the last the sensation and voluntary motion remained, so that he could walk about. After death the medulla oblongata was found entirely separated from the medulla spinalis, being only connected by a disorganized gelatinous mass, through which the *nervus accessorius* and the hypoglossus traversed; but the *par vagum* and *glosso-pharyngeus* of the left side were completely severed. Under and concealed by this diseased portion of the *medulla spinalis*, the tooth-like process of the *vertebra dentata* was found, pressing upon the diseased portion of brain. In another case, the sensibility and voluntary motion of the lower extremities remained until death, though the bodies of the vertebræ from the tenth dorsal to the sacrum were carious, the spinal column at this part bent to a sharp angle, and the medulla spinalis at this part softened, rotten, and almost destroyed, and several of the compound nerves separated from their origin, nearly four inches of the dura mater being wanting at this part. In another case, of nearly three years' standing, the sensibility and voluntary motion remained to the last, though a post mortem examination showed more than four inches of the medulla spinalis wanting, that space being filled with a reddish fluid. Many other remarkable cases are recorded of this kind. One by Dessault, of a complete division of the cord by a musket-ball, without paralysis. Another, communicated by M. Ferrein, of a soldier, from whose spine the point of a sword was extracted, which had traversed the vertebral canal and spinal marrow without occasioning paralysis, the patient having marched eighty leagues after the accident, but died almost immediately after the extraction of the fragment. These are, however, extraordinary exceptions to a general rule, considerable lesions of the medulla spinalis being generally attended with paralysis of the parts situated below the lesion.

M. Begin doubts the accuracy of these statements, but it would seem without sufficient authority. Though contrary to our general experience, they are not without analogy. Our knowledge of the mode in which innervation takes place is very imperfect, and many of the facts, therefore, connected with it are very obscure and inexplicable. We have seen what extreme disorganization of the cerebrum may take place, and yet the intellection continue normal.

* See Physiologie Pathologique, t. i., p. 243.

In the experiments of Dr. Wilson Philip on the effects of the division of the pneumogastric nerve, he found that the digestion of the rabbit did not cease entirely if the divided ends of the nerve were allowed to remain in contact.

Cerebro-spinal System of Nerves.

If we consider the cerebro-spinal axis the centre of the nervous system, and the cerebro-spinal nerves the media between it and the remote parts of the body, through the agency of which sensation and voluntary motion are executed, the inquiry naturally arises as to the action of these agents, the nerves. Notwithstanding the intimate connexion between sensation and voluntary motion, yet, viewed with respect to the encephalon, as the sensorium commune, their relations are widely different. The sensations obviously pass from the periphery of the nerves to the encephalon; the influence which produces voluntary motion, on the contrary, in an opposite direction. If we expose a sentient nerve, and irritate or cut it, the influence is propagated to the centre, and hence pain. But if it be a motor nerve, spasm or loss of motion will ensue in the part to which the nerve is distributed, but not pain. It would appear that the cerebro-spinal system acts in a circle. The nerves would seem to be so constituted that they can transmit their peculiar influence only in one direction. The sentient nerves receive impressions from without, which pass through them to the sensorium; the motor nerves transmit the mandates of the will, consequent upon these sensations. The following experiments, by Mr. Mayo, beautifully illustrate this circulation of nervous power. The iris derives its motor power from the third pair of nerves. It is well known that the use of this movable veil is to admit to the interior of the globe of the eye the quantity of light most favourable to the action of the retina. Its action is, therefore, intimately associated with the optic nerve. Mr. Mayo found that, on dividing the optic nerve, the motions of the iris ceased; but that, if he irritated that extremity of the divided nerve next to the brain, the iris again contracted. But no influence could be produced upon this muscle by irritating that extremity of the divided optic nerve attached to the globe of the eye. The plain interpretation of these phenomena is, that in the first experiment, an impression being communicated through a sentient nerve, the optic, to the brain, a corresponding influence was transmitted from the encephalon towards the circumference through the motor nerve, and hence the motion of the iris. This was confirmed by the effects of dividing the third pair, after which no motion of the iris could be produced by irritating either extremity of the divided optic nerve.

But though the division of the trunk of a nerve, by interrupting this circle, and cutting off the communication between the remote part and the sensorium, deprives it of sensation or motion for the time, yet this loss of power is not necessarily final. As proofs of this, we may refer to the experiments of Dr. Wilson Philip on the

division of the pneumogastric nerve in the rabbit, where the divided ends of the nerve were allowed to remain in contact. Cicatrization also sometimes takes place, and the function of the nerve is permanently restored. This has been so frequently observed by surgeons, after dividing the trigeminus in tic douloreux, and in other neuralgic affections, that they often remove a portion of the nerve to prevent a return of the disease. It has been questioned whether this restoration of the functions of the nerve is attributable altogether to the cicatrization, or whether the nervous influence is derived, to the parts situated beyond the point of division, from other nervous trunks in the neighbourhood. There are some remarkable and well-attested facts which favour the latter opinion. Thus, it is observed, that if the trunk of a nerve going to a part which is exclusively supplied by that nerve be divided, the function is never restored, *e. g.*, a division of the circumflex nerve, which alone supplies the deltoid, is observed to be followed by an incurable paralysis of that muscle. A similar result occurs in the leg and foot, on the division of the great sciatic nerve. —(*Begin*, t. i., p. 190.) It is not improbably owing to these relations that, after rheumatic affections of the deltoid, this muscle is so slow in recovering its power, and, indeed, often remains permanently paralyzed. This affords an explanation of one of the uses of the numerous interlacings and communications in the course and distribution of the nerves.

Inflammations and other affections of the tissues necessarily involve the periphery of the nerves, the minute filaments of which constitute one of their organic elements, and modify their functions. In every morbid condition of a part, there is, therefore, some change in its sensations, motions, and other functions. In the more common and active forms of disease, pain in the part is one of the most uniform symptoms of lesion in all the tissues. In our examination of those organs, which can only be approached by the taxis, in order to ascertain their pathological condition, our diagnosis, for the most part, is guided by the state of the sensations and functions of the part. If pain, morbid sensibility, and deranged function exist, we generally infer there is local inflammation. We so frequently find the morbid sensation indicate the seat of the disease, that, at last, we are apt to regard it as a certain guide. But, though in many cases the morbid sensation truly indicates the sentient extremities of the nerves as being the seat of the disease, yet it by no means uniformly holds good. In some cases, the pain or morbid sensation exists at the sentient extremity of the nerve, when the true seat of the disease is either in one of the central nervous masses from which the nerve is derived, or at some remote part of its trunk. A morbid condition of that portion of the encephalon from which a nerve is derived, or an injury inflicted upon the trunk at some intermediate point in its course, is not unfrequently indicated alone by pain or other morbid sensation in that texture to which the sentient extremity of the nerve is distributed. The inaccuracy of our sensations as

guides in this respect is strikingly shown in what frequently occurs after the amputation of a limb. In these cases, it is not uncommon for the patient to complain of pain in the severed extremity long after the operation. He sometimes feels as if its position were painful, and unconsciously makes an effort to change it. In affections of the medulla spinalis, or of the compound nerves at their origin, the patient often makes no reference to the seat of the disease, but complains of pains, spasmodic twitching, loss of sensation or motion, &c., in the parts to which the nerves are distributed.

Hence has often arisen the greatest obscurity in the diagnosis, pathology, and treatment of these diseases. The success of our practice, for the most part, depends on the correctness of our diagnosis, and addressing our remedies to the seat of the disease. If the morbid condition be at the encephalic extremity of the nerve, and the remedies applied to its periphery, our therapeutic efforts will be exceedingly apt to fail. Thus, neuralgic affections of the eye, teeth, and face often exist together, which can only be relieved by ascertaining the original seat of the disease, and addressing our remedies to it.—(See *Marshall Hall on the Reflex Functions of the Medulla Oblongata*, p. 40.) The morbid sensibility of the part is, in some instances, a sufficient guide, but in others it is entirely inadequate. In that extensive class of diseases called the neuroses, including angina pectoris, tetanus, hydrophobia, epilepsy, hysteria, chorea Sancti Viti, &c., until very recently, all the reasonings of pathology were set at defiance; mere empiricism being the only guide in their diagnosis and therapeutic treatment. It is not pretended that this obscure department of pathology has been stripped of all its difficulties, but great light has certainly been thrown upon it by modern investigations of the functions of the nervous system.

In the neuroses, there are a great number of anomalous symptoms quite inexplicable, according to the theoretical opinions formerly entertained on this subject. The most common and prominent are characterized by morbid sensations in parts which are obviously not the true seats of the disease. In the globus hystericus, the morbid sensation points to the stomach; the aura epileptica, to one of the limbs; the pain under the left mamma in chronic hysteria, to the lungs, &c., as being the seats of disease. But it is now admitted that, in a great majority of cases, these indications are false. Though the more remarkable sensations exist at the periphery of the nerves, where they are lost in the textures of the organs, yet it is apparent that the irritation is generated about the origin of the nerves, or perhaps the encephalon itself.

When inflammation occurs in a texture, it not unfrequently happens that the irritation is propagated for a considerable distance along the trunks of the nerves distributed to the part. Thus, in chronic inflammation, thickening and change of structure are sometimes induced in the trunk of the nerve, attended with severe neuralgic pains and spasms about the parts to which the nerve is

distributed. Similar consequences also often arise from punctured, contused, and lacerated wounds of the trunks of the nerves. In other instances, the morbid effects are propagated towards the origin of the nerve, sometimes even involving the encephalon, inducing abscesses of the brain, epilepsy, convulsions, tetanus, &c.

Again: In health, it appears that impressions made on the sentient extremities of the nerves are propagated towards the centre, and are exactly represented to the sensorium. But lesion of the nerves of sensation, either at their encephalic or sentient extremity, or at any intermediate point, will derange the accuracy of the impression. The circumstances will often enable us to determine with considerable certainty the seat of the lesion. When we see, *e. g.*, a black spot, looking like an insect flitting before the eye, in whatever direction the organ is moved, the health in other respects being little disturbed, we infer that it is caused by the imperfect innervation of some spot upon the retina. But when the encephalic extremity of the nerve, perhaps the encephalon itself, is the seat of disease, though the impression made upon the organ of sense be accurate, yet the image presented to the mind is false or distorted. It would appear probable that the phenomena observed in delirium are produced in this way. Though the eyes and the ears may appear to be perfect in their organization, and prompt in their action, yet things are no longer perceived as they are actually. The patient sees objects which do not exist, and hears sounds that are not made, and holds conversation with imaginary beings. In excited states of the brain, as in the earlier stages of acute diseases, there is coherency of thought, and the perceptions, though exaggerated or false, at least possess some verisimilitude. But where the vital powers are prostrate, as towards the close of violent diseases, not only are the perceptions false, but the thoughts incoherent and wandering, constituting what is called low, muttering delirium. The mind possesses a certain influence over the perceptions; even in health, our thoughts impart a character to the objects we are contemplating. With a little effort, especially if objects be imperfectly seen, we can thus distort them into innumerable fanciful forms, giving to them the shape and hue of our own thoughts. In certain morbid conditions, where the intellection could scarcely be said to be disturbed, and where the organs of sense exhibited no outward evidence of disease, individuals have witnessed the most extraordinary visions. In some instances, these spectral illusions have been seen for a length of time, and examined with a minuteness of detail, that it required no ordinary force of intellect to recognise the phenomena as imaginary, the result of a morbid condition of the organism. We thus perceive that delirium is generally an unfavourable symptom, as it indicates disease and loss of power in the centre of the nervous system.

Action of the Cerebro-Spinal System of Nerves.

It is a general law of the nervous system, that one nerve con-

fers but one property upon the part to which it is sent, according to the portion of the encephalon from which it is derived. In the trunk and extremities, sensation and voluntary motion are the principal offices; the nerves sent to these parts are, therefore, few in number, and simple in their distribution. The face presents a striking contrast in this respect; in this space a great number of important organs are assembled, and distinct acts executed; not only common sensation and voluntary motion to be performed, as in other parts, but various sensations pertaining to the organs of the senses, and both voluntary and involuntary motions. Inconceivably delicate and complicated muscular motions are executed here with extreme rapidity, and in exact unison. It is sufficient to allude to a few of these functions, viz., vision, audition, smell, taste, respiration, deglutition, the voice, expression, &c., to illustrate this. Hence the great number and complexity in the arrangements of the cerebro-spinal nerves sent to this part, which renders their study extremely obscure and difficult. This obscurity is, however, diminished by the fact that whereas, in the trunk and extremities, sensitive and motor filaments are bound in the same sheath, and sent to remote parts like one nerve, in the face each nerve generally runs separate, from its origin to its distribution.

It may be inquired, Why are the voluntary muscles also supplied with sentient nerves? It may be replied, that the muscles are not exclusively destined to motion, but that their action is also governed by the resistance which they are intended to overcome, and that this resistance can only be known by the agency of the sentient nerves. Thus, in cases of anasthesia, in which the sentient filaments are paralyzed, while the motor nerves retain their power, the utility of the latter is greatly impaired. We could not retain a lifted weight, or balance the body in standing or walking, were not the action of the muscles regulated by the sentient nerves. The sensibility of the muscles differs from that of the skin probably rather in kind than in degree. The offices of the integument demand the power of perceiving promptly the action of external agents, it being the sentinel by which the organism is guarded from noxious influences from without. Hence it is highly susceptible to that modification of sensibility which is manifested by pain.—*Ed.*]

CHAPTER XI.

OF MUSCULAR CONTRACTION AND THE VOICE.

The functions which we have now examined depend entirely on the faculty of perception. It is by this faculty that we arrive at a knowledge of the objects which surround us, and of ourselves.

To terminate the history of the functions of relation, it only remains for us to speak of those functions by means of which we act upon foreign bodies, impress upon them the changes which we judge necessary, and express our sentiments and ideas to those by whom we are surrounded. These functions are but different shades of the same phenomenon, *muscular contraction.* So that the faculty of perception on the one side, and muscular contraction on the other, constitute really all our life of relation. We shall first define muscular contraction in general; after which we shall treat of its principal results, voice and motion.

Muscular contractility, which has also been called animal and voluntary contractility, is not a simple vital property, at least in the sense which we attach to this word. It results from the successive or simultaneous action of several organs, and ought, therefore, to be viewed as one of the natural powers.

Apparatus of Muscular Contraction.

The organs which concur in muscular contraction are the brain, nerves, and muscles.

Of the Parts of the Encephalon which appear more particularly destined to Motion.

Certain parts of the cerebro-spinal system appear more particularly destined to motion. In proceeding from the anterior to the posterior part, there are the corpora striata, the inferior portion of the optic thalami, the crura cerebri, the pons varolii, the peduncles of the cerebellum, the lateral portions of the medulla oblongata, and the anterior fasciculi of the medulla spinalis. We shall soon cite facts on which we rely to show that these parts have a remarkable influence in the production of muscular contraction.

Nerves of Motion.

Anatomists have long sought to distinguish the nerves which confer sensibility from those which are specially destined to motion. They have been induced to pursue this investigation with the more zeal, as we daily see these two phenomena isolated by disease. We frequently see instances where a part will lose its sensibility and preserve its power of motion, and the reverse. I have had the happiness to establish this distinction by experiment, and it is generally known, since the publication of my work, that the anterior roots of the spinal nerves are the essential nerves of motion to all parts of the trunk and the extremities.

With respect to the face, it is evident, from one of the most beautiful experiments of Sir Charles Bell, that the nerve of the seventh pair is particularly the organ which imparts the power of motion to the eyelids, cheeks, and lips. Experiment has also taught us that the hypoglossal nerve and the glosso-pharyngeus are more particularly destined to the motions of the tongue; that the muscular portion of the fifth pair directs those of the jaw; and

that the third, fourth, and sixth pairs concur more especially in the motions of the iris and the globe of the eye. We shall return to the consideration of these new facts under the head of partial movements. I have given in another place the experimental proof that the eighth pair directs the motions of the glottis, as we shall see in the article *Voice.*

Messrs. Prevost and Dumas have been recently occupied in examining the structure of the nerves that are distributed to the muscles, and their manner of distribution in the midst of the muscular fibres. A great number of observations made with the microscope on the nerves of the rabbit, the Guinea pig, and the frog have taught them, 1st. That, when magnified ten or fifteen times, the nerves present on their surface alternately white and dark bands, which strikingly resemble a spiral line under the cellular envelope. But this appearance is illusory; it depends simply on a small fold of the envelope, which loses its transparency in some points, and preserves it in others. The proof of this is, that if we draw slightly the nervous filament, while placed under the lens, it disappears.

If we take a nerve, and after having divided it longitudinally, we place it under water, we shall find that it is composed of a great number of small filaments, parallel to each other, and of equal size. These filaments are flat, and composed of four elementary fibres, arranged nearly in the same plane. These fibres are composed of a series of globules. (See plate, t. iii. of my *Journal de Physiologie*). Messrs. Prevost and Dumas have computed that 16,000 of these fibres may be contained in a cylindrical nerve of a millimetre in diameter, as, for example, the crural nerve of a frog.

Of the Muscles.

All the muscles, taken collectively, are called the muscular system. The form and disposition of the muscles vary infinitely. Muscles are formed by the union of a certain number of muscular fasciculi, which are again composed of still smaller bundles; these, again, are formed of fasciculi of a smaller volume; and thus, by excessive subdivision, we get a fibre extremely small, and which we can no farther divide, but which might probably be farther divided if our senses and means of division were more perfect. This fibre, which is indivisible by us, is called *the muscular fibre.* It is formed by a series of globules, which are kept in a right line by amorphous matter. It is longer or shorter, according to the muscles of which it constitutes a part; almost always straight, it does not divide, nor is it confounded with other fibres of the same kind; it is enveloped in a cellular tissue, extremely delicate; it is soft and easily torn in the dead body, but, on the contrary, in the living body it exhibits a resistance, in proportion to its volume, which is surprising; it is essentially composed of fibrine and osmazome; it receives much blood, and at least one nervous filament. Some anatomists have pretended to explain

how the bloodvessels and nerves act when they arrive in the tissue of the muscular fibres, but nothing satisfactory has been advanced upon this point.

The researches on this subject on which we can place the most reliance are those of Messrs. Prevost and Dumas. These learned naturalists have followed with the microscope the distribution of the nervous fibres, and they assure us that they are not confounded or gradually blended with the muscles, but that they form a network (*un anse*), which extends from one nerve to another, so as to return back towards the encephalon, after having traversed the muscle. According to the same authors, each nervous filament has one extremity at the anterior fasciculus of the medulla spinalis, that it descends towards the muscle, constituting a part of a nervous trunk, and after traversing one or more muscular fibres, it then passes back, and is attached to the posterior fasciculus of the medulla spinalis.

Each muscular fibre is attached, at its extremities, by fibrous prolongations (tendons or aponeuroses), which are the conductors of its force when it contracts itself. Muscular contraction, as it exists in the ordinary state of life, supposes a free and easy action of the brain, and the nerves which are sent to the muscles, and of the muscles themselves. Each of these organs must receive arterial blood, and the venous blood not be permitted to remain in its tissue for too great a length of time; if either of these conditions be wanting, muscular contraction becomes either impracticable, perverted, or very weak.

Phenomena of Muscular Contraction.

When examined with a weak magnifying glass, the muscular fibres which form a muscle are parallel and straight while in a state of repose, but much inclined to change their position. If by any cause the muscle contracts, there is immediately apparent in the muscular fibres a very remarkable phenomenon, which had been only vaguely noticed before the time of Messrs. Prevost and Dumas. The fibres become bent into a zigzag, and present a great number of angular undulations, regularly opposite to each other. If the cause that induced the contractions suddenly ceases, the parallelism of the fibres is restored.

In repeating this experiment, we cannot fail to observe that the flexions of each fibre take place at certain determinate points, and never at any others. The strongest contractions do not cause angles of more than fifty degrees. It is an interesting fact observed by Messrs. Prevost and Dumas, that the nervous filaments which traverse the muscular fibres pass precisely at those points where the angles of flexion are produced, and in a direction perpendicular to the fibres.

The same authors think they have proved, by precise observations, that the contracted, or, rather, angular muscular fibre, is not shortened. Thus, during contraction, the extremities of the fibre approach each other, but that the fibre itself loses nothing in

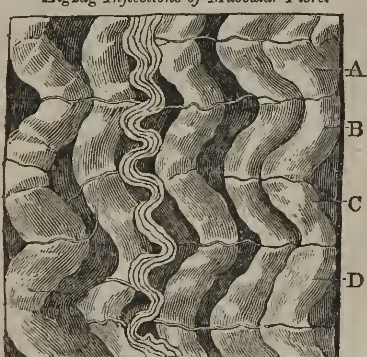
its length. They have arrived at this result either by measuring directly the contracted muscular fibre, or by calculating the angles produced.

It has long remained doubtful whether the muscles in mass, in a state of contraction, are increased or diminished in volume. Borelli alleged that they increase ; Glisson the reverse, which he maintained by an experiment. He plunged his arm into a vessel filled with water, and thought he could perceive a diminution of the level of the liquid at the moment the muscles were contracted. This experiment was cautiously repeated by M. Carlisle, with an opposite result. But it is evident that this mode of experimenting does not admit of the necessary precision, inasmuch as no allowance is made for the changes which may take place in the skin and cellular tissue.

M. Barzoletti has made an experiment on this subject which is quite conclusive. He suspended in a bottle the posterior half of a frog. He then filled it with water and closed it up, a graduated tube passing through the cork. He then caused the muscles to contract by means of galvanism, but he could not perceive that it had any influence in changing the level of the fluid in the tube. Thus it is evident that the volume of the muscles is not changed by contraction.

[The following figure, from Müller, represents the zigzag inflexions of the muscular fibre described by MM. Prevost and Dumas.

(Fig. 25.)
Zigzag Inflections of Muscular Fibre.



They regard each muscular fibre as consisting of a number of short lines, A, B, C, D, and suppose that the shortening of the muscle during its contraction is due to the above-described angular inflexions of the fibres. But Müller and other accurate observers have questioned whether this is the sole or even essential cause of the shortening of muscles. Professor Owen and Dr. A. Thompson allege that this zigzag arrangement of the fibres does not occur until the contraction has ceased.

According to Müller, there are two forms of primitive muscu-

lar fibrils: 1st, simple uniform filaments; 2d, those having a varicose or beaded structure.

1st. Those with simple primitive fibres, and destitute of transverse striæ, compose the muscular coat of the intestines. Schwann could not detect transverse striæ either in the human uterus, or that of the rabbit, or the urinary bladder.

The second class of muscles, the primitive fibres of which present a beaded structure, and which have cross markings, have been much more carefully examined than the first. When viewed with the microscope, the beading or cross marking is seen distinctly; they are remarkable for the rapidity and strength of their contractions. This second class includes generally all the muscles of both voluntary and involuntary motion, which are remarkable for their deep red colour (*Müller*), though they are not all of this colour; they are also distinguished for their strength and the rapidity of their contractions.

(Fig. 26.)

Muscles with Beaded Filaments.

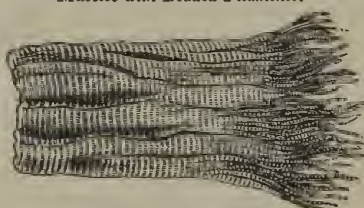


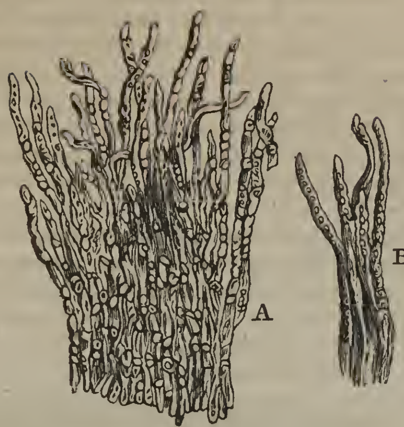
Figure 26, taken from Müller, represents a portion of a broken muscular fibre of animal life, magnified about seven hundred diameters, showing the apparently beaded form of the filaments and the production of the transverse striæ by the transverse parallel opposition of the beads of the filaments.

The transverse striæ of the primitive fasciculi, when examined by the microscope, are seen to follow each other very closely, and are quite parallel.—(*Müller*). The beaded enlargements of the different fibrillæ appear to have a close adhesion to each other; so that we may consider the fibre as not only made up of longitudinal filaments, but of disks (*Carpenter*), formed by the lateral adhesion of the beads, and connected together by their intervening narrow bands.

The following figure (No. 27) represents organic muscular fibres, magnified three hundred diameters, showing their flattened form. Most frequently, as at A, the fibres present, at successive points, transparent bodies of various forms, of which the majority are contained within the substance of the fibres, and are probably the nuclei of the primary cells that have coalesced to form them. In some fibres these bodies are not seen, having in all probability been absorbed (*Müller*), as at B.

(Fig. 27.)

Organic Muscular Fibres.



The following is a representation, after Bowman, of a portion of human muscular fibre, separating into disks by cleavage of the transverse striæ.

(Fig. 28.)

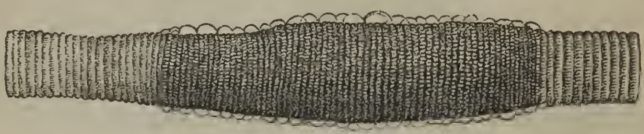
It would appear from the recent observations and experiments of Mr. Bowman, that in a state of contraction there is an approximation of the transverse striæ, and a general shortening of the fibre, and that its diameter is at the same time increased; but that it is never thrown out of the straight line, except when it has ceased to contract, and its two extremities are still held in proximity by the contraction of the other fibres. He states that the whole process may be distinctly seen under the microscope in a single fibre isolated from the rest; for this he recommends fibres from the crab and the lobster. The contraction commences usually at the extremities of the fibre, but it frequently occurs also at one or more intermediate points. The first appearance is a spot more opaque than the rest, caused by approximation of the transverse striæ, and the shading caused by the approximation of a few segments of some of the fibrillæ. This shading, caused by the approximation of the transverse striæ, increases in intensity, until it extends through the whole diameter of the fibre. The striæ are found to be two, three, and even four times more nu-

merous in the contracted than in the uncontracted portion, and proportionally narrower, and more delicate. The line of demarcation between the contracted and uncontracted portion is well defined, fresh striæ being, as it were, absorbed from the latter into the former as the process goes on. The contracted part augments in thickness as the process goes on, but not in a degree proportioned to the diminished length; so that the solid parts lie in a smaller compass than before, the fluid which previously intervened between them being pressed out into bullæ under the sarcolemma.

This appearance is illustrated, after Bowman, in the following figure of the muscular fibre of the Dysticus, contracted in the centre; the striæ approximated, the breadth of the fibre increased, and the sarcolemma raised in bullæ on its surface.

(Fig. 29.)

Muscular Fibre contracted in the Centre.



The force with which the elements of the fibre thus tend to approximate is evidently considerable; for if the two extremities be held apart, the fibre is not unfrequently ruptured. This corresponds with an appearance often observed in the muscles of persons who die of tetanus. In the ruptured fibres of those muscles which had been the subject of the spasmodic action, the striæ have been observed to approximate so closely as to be scarcely distinguishable.

Many facts appear to indicate that, when a muscle is even in vigorous action, all its fibres do not contract at the same moment, but that there is a continual interchange, by which the tension is effected, some relaxing while others are shortening. When the ear is applied to a muscle in powerful action, an exceedingly rapid, faint, silvery vibration is heard, which seems to be attributable to this constant movement in its substance. On examining a muscle in this state, some fasciculi present a zigzag arrangement, while others will be seen to be quite straight, and in a state of contraction. From this it would appear that the former arises from fasciculi that have either not entered into contraction, or have relaxed after being in this state, but of which the extremities are still approximated by the action of the contracting fibres. Though, as will appear from what has been said, we know very little of the mechanism of muscular contraction, yet, from the fact that a single muscular fibre, isolated from all other tissues, can pass into a state of complete contraction when subjected to certain stimuli, the important inference may be drawn that *contractility* is a property inherent in this tissue, and not necessarily dependant upon nervous agency, though usually called into action by it, in the living body.

Muscles may be thrown into contraction, so long as they preserve their vitality, by various chemical and mechanical agents, as cold, heat, electricity, &c. They do not lose their vitality immediately with the cessation of the circulation and the occurrence of apparent death. This property lingers longer in some animals and in certain tissues than in others. It is retained much longer in cold-blooded animals than in the vertebrata. It appears, from the experiments of Nysten on the bodies of criminals executed in good health, that in the human subject, the irritability of the muscular fibre ceases in the different structures in the following order: The left ventricle of the heart, intestinal canal, urinary bladder, right ventricle of the heart, œsophagus, muscles of animal life; lastly, the auricles of the heart, especially the right. In the first, it disappears in from forty-five to fifty-five minutes; the last, the right auricle of the heart, has been known to contract, under the influence of galvanism, sixteen and a half hours after death. The muscles of young animals retain their irritability longer than those of adults. Muscular contractility is weakened or destroyed by many substances, especially those which have a sedative or narcotic effect. A watery solution of opium, applied to the muscles or injected into the veins, exerts a powerful effect in this respect. The same effect is produced by venous blood, charged with carbonic acid and deficient in oxygen, as occurs in those who have died from gradual, and, therefore, prolonged asphyxia; the same influence appears in the consequences of *morbus coruleus*, in which the patient is incapable of much muscular exertion.

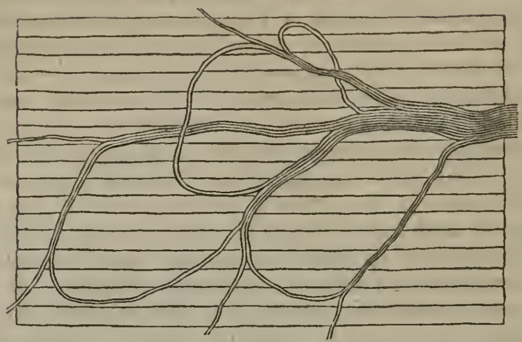
It appears to be a general law of muscular contraction that it shall alternate with relaxation at no long interval. This remark equally applies to the muscles of animal and organic life. The contractile power of muscles, especially those of animal life, is developed by exercise and weakened by inaction, the nutritive process being increased by the former and lessened by the latter. This is shown by the muscular development of the arms of the blacksmith, and that of the lower extremities in the opera-dancer. When the muscles are long disused, not only is their bulk diminished, but the muscular fibre sometimes disappears and degenerates into fat, mingled with the fibrous tissue. The motor nerves cannot be said *to terminate in the muscles*, in the sense in which this expression is ordinarily used, *i. e.*, to be lost in their structure in minute filaments. The trunks of the nerves form a sort of network in the substance of the muscles, the fibres forming loops, as may be seen in Fig. 30, after Burdach, on the following page.

The nature of the stimulus communicated by the nerves, and the mode of its communication, are at present mere matters of conjecture. Some similarity has been supposed to exist between the voluntary action of the muscles and that excited by galvanism; but these agencies are obviously merely analogous, not identical: other agents, both physical and chemical, produce the same effects.*

* Carpenter.

(Fig. 30.)

Loops of Nervous Fibres in Muscles.



The *rigor mortis*, or stiffening of the body after death, is evidently a phenomenon connected with muscular contractility. This almost invariably occurs, though sometimes so slight and evanescent as to escape observation. It varies in the degree, the period at which it takes place, and its duration, very much, according to the vital condition at the time of death. In protracted, wasting chronic diseases, and those attended with great exhaustion of vital energy, as typhoid fever, the rigidity occurs early, sometimes in fifteen or twenty minutes, and soon passes by. This remark also applies to young children and old persons. On the contrary, where the death has been sudden and violent, as from certain poisons, asphyxia, blows upon the stomach, lightning, &c., the rigidity is often protracted and slight, and sometimes does not occur at all. This rigor mortis is evidently not dependant upon temperature, as some have supposed, as it occurs in cold-blooded animals, and often in warm-blooded, even before there is any essential loss of heat. The muscular contraction appears to be dependant upon nervous agency, sometimes rendering the muscles prominent, as in voluntary contraction. The passing away of this state is soon succeeded by decomposition. There is a resemblance between this state and the coagulation of the blood, though this is rather analogical than identical; like it, it is the last vital phenomenon connected with muscular contractility. This phenomenon sometimes becomes important in settling questions connected with juridical medicine.*]

When a muscle contracts, its fibres grow shorter and harder more or less suddenly, without any oscillation or preparatory hesitation; they immediately acquire such a degree of elasticity that they become susceptible of vibrations, or of producing sounds. The colour of the muscle does not appear to change at the moment it contracts, but it has a tendency to displace itself, which is counteracted by the aponeurosis. All the sensible phenomena of muscular contraction take place in the muscles themseives, but it is not the less certain that these depend upon the

* Applications of Muscular Power, Carpenter, p. 314, sections 395–6.

action of the brain and nerves. Compress the brain of an animal, and it loses the power of contracting its muscles. Cut the nerves which are distributed to a muscle, and it becomes paralyzed. We are completely ignorant of the changes that take place in the muscular tissue during contraction. In this respect, muscular contractions cannot be separated from other vital actions, of which we can give no explanation; not but that there have been many attempts to explain, not only the action of the muscles, but also that of the nerves, and even of the brain, in muscular contraction; but there is no hypothesis which has yet been proposed that can be considered at all satisfactory.*

Instead of consuming our time in such speculations, which it is always easy both to invent and refute, and which should long since have been banished from physiology, we may much more profitably employ ourselves in investigating muscular contraction as it relates, 1st, to its intensity; 2d, its duration; 3d, its rapidity; 4th, its extent.

The degree of force with which the muscular fibres shorten themselves is generally regulated by the action of the brain. It is, in general, submissive to the will, varying in degree in each individual. A particular organization of the muscles is favourable to the intensity of its contractions; this exists when the fibres are voluminous, firm, of a deep red colour, and presenting transverse striæ. With an equal effort of the will, they produce greater effects than those muscles, the fibres of which are small, smooth, and of a light colour. Nevertheless, when muscles, the fibres of which are of this last description, are placed strongly under the influence of the will, the intensity of the contraction may be very great; so that cerebral influence, and the disposition of the muscular tissue, are the two elementary principles on which the intensity of muscular contraction depends.

It is rare that we find in the same individual very energetic cerebral action, united with a disposition of the muscular fibres, favourable to intensity of contractions; it almost always happens that these two principles are opposite to each other. When they happen to be united, they produce astonishing effects. This was probably the case with the athleti of antiquity, and is sometimes observed in the jugglers of the present day. By the influence of the action of the brain alone, muscular power may be exerted to an extraordinary degree. We know very well the astonishing strength of some men in anger, that of maniacs, and of persons in convulsions, &c.

This is, in some degree, dependant upon the will, but it cannot be prolonged beyond a certain period, which varies in different individuals. After this, a sense of fatigue is induced, slight at first, but which, at last, increases to such an extent that the muscle refuses to contract. The promptitude with which this sensa-

* I do not even except the electrical fluid, considered by some as having a certain influence in this phenomenon. It appears, from the ingenious experiments of M. Perron, that no trace of electricity is developed during muscular contraction.

tion of fatigue is induced, is in proportion to the intensity of the contraction and the weakness of the individual. To obviate this inconvenience, the different motions of the body are so calculated that the muscles act successively; the contraction of each does not, therefore, continue long. We can thus explain why we do not remain long in the same position; why an attitude, which requires the strong and continued contraction of a small number of muscles, cannot be continued long. The sense of fatigue which follows muscular contraction is dissipated by a state of repose, after which the muscle recovers its power of contraction.

To a certain extent, rapidity of contractions depends on cerebral influence. This is proved by our ordinary movements, but it also sometimes depends upon habit. Observe, for example, what a difference exists as relates to rapidity of muscular contractions, between a man who for the first time puts his hands upon the keys of a piano, and the same individual after he has been in the habit of practising for several years! We observe a very remarkable difference between individuals as respects quickness of contraction, both in the common movements and in those which require an appropriate exercise.

This is directed by the will, but it must necessarily vary with the length of the fibres, for long fibres must have a more considerable extent of contraction than those which are shorter.

From what has been said, we perceive that, in general, the will has a great influence upon the contraction of muscles. But this is not indispensable. In a great number of instances, these motions are executed, not only without its participation, but in opposition to it. We find many remarkable examples of this in the effects of habit, passions, and diseases.

We must not confound muscular contraction, such as we have now described it, with the modification it undergoes in certain diseases, such as convulsions, spasms, tetanus, wounds of the brain, &c. We must, likewise, take care not to confound that contraction of which we are now speaking with the phenomena which the muscles present for some time after death. Without doubt, these phenomena are curious, and worthy of examination, but they certainly do not merit the importance which has been attached to them by Haller and his disciples, especially as it is not proper to unite them, under the name of irritability, with the other modes of contraction which are observed in the animal economy, and particularly with that of muscular contraction.

Modification of Muscular Contraction by Age.

It is only at the commencement of the second month that we can distinguish the muscles from the gelatinous mass which constitutes the embryo. At this period they do not present any of those characters by which they are distinguished in the adult. They are then of a pale gray colour, slightly tinged with red, and receive but a small quantity of blood, comparatively speaking. They increase and develop themselves with the progress of its

growth, though, even at the period of birth, they are small, flaccid, and indistinct. We must except, however, those which assist in digestion and respiration, which are developed in a remarkable manner.

During infancy and youth, the nutrition of the muscles becomes increased, and they grow, particularly in length. This is the reason of the slenderness and agreeable rotundity which we observe in the forms of children and young persons. When a person arrives at the adult age, the form undergoes a total change; the muscles increase, and project strongly against the skin; the intervals which separate them being no longer filled with fat, projections and depressions are formed, which give to the body an entirely different aspect from that of childhood. At this age, the muscles assume a greater degree of consistence, the colour becomes of a deeper red, and even the chemical characters are modified. We learn from daily experiments that, when the flesh of young animals is boiled, the flavour, colour, and consistence of the broth differ very much from that of an adult animal. It appears that the muscles of adult animals contain more fibrine, osmazome, and the colouring matter of the blood; of consequence, more iron.

The nutrition of the muscles diminishes sensibly in old age; they diminish in volume, grow pale, and become flaccid and unsteady, especially in the extremities; the contractility of the tissue is weakened, the fibre becomes coriaceous, and is torn with difficulty. The preparation of muscular flesh is also very different in our kitchens according as the animal is young or old.

Muscular contraction undergoes nearly the same changes as the nutrition of the muscles. Weak, and hardly distinguishable in the fœtus, its activity is augmented at birth, increases rapidly in childhood and youth, acquires its highest degree of perfection in the adult age, and finishes by being nearly lost in decrepitude.

OF THE VOICE.

We understand by the voice the sound produced in the larynx, at the moment the air traverses this organ, either to enter into or pass out from the trachea.

For the purpose of explaining the mechanism by which the voice is produced and modified, we shall say a few words of the manner in which sound is produced, propagated, and modified in wind instruments, especially in those which have the greatest analogy with the organ of voice.

In general, a wind instrument is formed by a straight or curved tube, in which the air is thrown into a state of vibration by various processes. Wind instruments are of two sorts; the one is called a mouth, the other a reeded instrument.

The *mouth instruments* include the horn, trumpet, flagelet, flute, and the flute tube of the organ. In all these, the column of air is contained in the tube, which is the sonorous body. In order that it may produce sound, it is necessary that vibrations

should be excited. The means employed for this purpose vary according to the kind of instrument. The length, size, form of the tube, the openings formed in its side and its extremities, the force and manner with which the vibrations are excited, are the causes of the variety of sounds in different instruments. The nature of the substance of which they are formed only influences the *timbre* of the sound. The theory of these instruments is precisely similar to that of the vibration of longitudinal cords. When we know the physical condition of one of these instruments, we can determine with accuracy, by calculation, the sounds which it will produce. There is nothing obscure in this theory, except some point relative to the mouth-piece, that is, the manner in which the vibrations are excited. There is no very evident resemblance between this kind of instrument and that of the voice.

It is more important for us to understand reeded instruments, because the organ of the voice is of this kind. Unfortunately, their theory is much less perfect than that of mouth instruments. We include in this kind of instruments the hautboy, bassoon, clarinet, and the organ of the human voice. We may divide these instruments into the reed and the body, or tube; the mechanism of these two parts is essentially different.

The reed is formed sometimes of one, and at others of two thin plates, which are capable of moving very rapidly, and the vibrations of which are destined alternately to intercept, and transmit a current of air. This is the reason why the sounds thus produced are not governed by the same laws as those formed by elastic plates, free at one end, and fixed at the other, which excite immediately sonorous undulations in the open air. In reeded instruments, the reed alone produces and modifies the sounds. If the reed be long, the motions are extensive and slow; of consequence, the sounds are grave. A short reed, on the contrary, produces, necessarily, acute sounds, because the alternate transmission and repression of the current of air are more rapid. The most perfect reed, and which gives the most agreeable sounds, is that invented by M. Grenier, or, rather, imitated by him from the Chinese. When we wish to draw from a reeded instrument a variety of sounds, it is necessary to vary the length of the reed. This is done by those who play upon the bassoon, clarinet, &c., when they wish to produce different sounds with these instruments.

We may add, however, as an important circumstance, that the elevation of the note produced by an instrument depends, in part, on the elasticity, weight, and even form of the reed, and the intensity of the current of air; for when these circumstances vary, the length remaining the same, the note alters.

We never employ the reed alone, but adapt it always to a tube, through which the air passes when it is forced through the reed, and which must, for this reason, be open at both extremities. The length and rigidity of the tube does not influence the

tone of the sound, but only the intensity of the *timbre*, and the possibility of making the reed *speak*. If it be formed by membranous laminæ, which vary in thickness, elasticity, and tension, they may essentially affect the tone, as shown by the beautiful experiments of M. Savart. Short tubes especially modify the intensity. Those which determine the most brilliant sounds are conical tubes, which enlarge as they approach the part where the air escapes. If the cone be reversed, the sound becomes dull. But if two equal cones, opposed base to base, are adjusted to a conical tube, the sound becomes round and strong. The reason of these modifications has never been given by natural philosophers.

A column of air vibrating in a tube can produce only a certain number of determinate sounds. In consequence of this, a reeded instrument, when it is long, can only transmit distinctly those sounds which it is intended to produce; it is also necessary to establish at first a certain proportion between the reed and the body of the instrument. Of consequence, when we wish to draw a succession of different sounds from the same reeded instrument, it is necessary not only to vary the length of the reed, but to modify also, in a corresponding manner, the length of the tube; now this end is attained by piercing the sides of the bassoon, clarinet, &c., with small holes. By opening or closing these, we can make the reed and the tube bear such a proportion to each other as may be convenient. This agreement, likewise, enables us more easily, by means of the lips, to give the instrument the sound which we wish to produce. This influence of the tube is very remarkable in those instruments which are narrow (clarinets and hautboys). It is even to such an extent that the effect produced by the reed is very imperfect, if the tube be not suited to it. When the tubes are very large, as in organs, the reeds vibrate almost as freely as in the open air. We know not precisely what are the movements which take place in the air contained in such tubes, when they transmit the sound produced by the reed. We have seen above that the reverse is the case in mouth instruments.

Apparatus of the Voice.

Inasmuch as the passage of the air through the larynx is a condition absolutely necessary to the formation of the voice, we must include all the organs which produce this effect among the number of the vocal organs. There are many parts which assist in the formation or modification of the voice; but, before speaking of them, we shall more particularly insist here upon the larynx, which must be considered more especially as the organ of voice.

This organ is placed at the anterior part of the neck, and forms that remarkable projection which exists between the tongue and the trachea, and varies according to the age and sex. It is small in children and females, but is much more developed in the adult. The larynx not only produces the voice, but it is also the agent

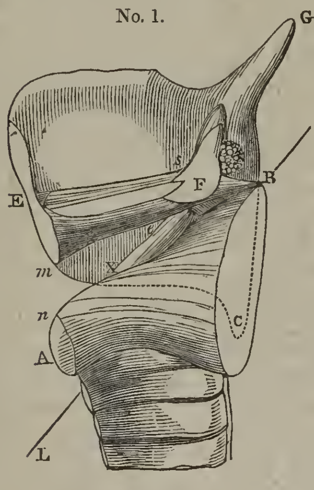
of its principal modifications. This is the reason why an exact knowledge of the anatomy of this organ is indispensable, if we wish to comprehend the mechanism of the voice. In consequence of not paying a sufficient attention to this point, very imperfect, or even false ideas, have been propagated on this interesting subject. We cannot enter here into all the details of the structure of the larynx, but we shall dwell more particularly upon those parts which are most necessary to be known, many of which are at present but little understood.

[The larynx is placed at the summit of the trachea, its lower portion consisting of the strong bony annulus called the cricoid cartilage. This is embraced, as it were, by the thyroid cartilage, which is articulated to its sides by its lower horns, around the extremities of which it may be regarded as turning as on a pivot.*

The following figures, numbers 1 and 2, taken from Willis, show the general arrangements of this organ. No. 1 presents a vertical section of the larynx and upper part of the trachea. No. 2 is a lateral and external view of the same parts.

(Fig. 31.)

No. 1.



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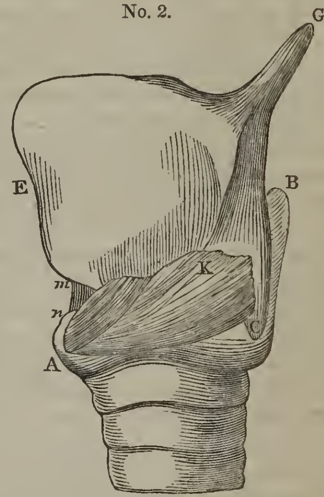


A n B is the cricoid cartilage; E C G, the thyroid cartilage; G is its upper horn; C is its lower horn, at which it is articulated with the cricoid. F is the arytenoid cartilage; E F, the vocal ligament. A K, No. 2, is the crico-thyroideus muscle; F m, No. 1, the thyro-arytenoideus muscle. X F, No. 1, the crico-arytenoideus lateralis muscle; s, a transverse section of the arytenoideus transversus muscle. m n is the space between the thyroid and cricoid cartilages; B L, projection of the axis of articulation of the arytenoid with the thyroid.

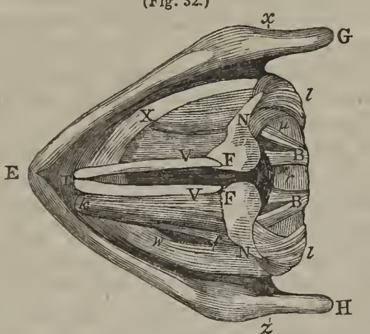
Thus it will be seen that the lower front border of the thyroid

* Carpenter.

cartilage, which is generally separated by a small interval from the upper margin of the cricoid, may be made to approach or recede from it. This any one may easily ascertain by placing his finger on the little depression, which may be felt readily externally, and observing its changes of size, while a range of different notes are sounded. It will then be observed that the higher the note, the more the two cartilages are made to approximate ; while they separate in proportion to the depth of the tones. In making this observation, the finger must be made to follow the general movement of the larynx, up and down.*

The following bird's-eye view of the glottis, after Willis, will assist us in forming an idea of the mechanism of the larynx.

(Fig. 32.)



G E H is the thyroid cartilage, embracing the ring of the cricoid *r u X w*, and turning upon the axis *x z*, which passes through the lower horns C (last figure). N F are the arytenoid cartilages, connected by the arytenoideus transversus T V. T V are the chordæ vocales, or vocal cords or ligaments, which stretch across from the summit of the arytenoid to the point of the thyroid cartilage. It is evident that they will be rendered more or less tense by the movement of the thyroid, being tightened by the depression of its front upon the cricoid, and relaxed by its elevation. On the other hand, they may be brought into more or less close apposition by the movements of the arytenoid cartilages, being made to approximate closely, or to recede in such a manner as to cause the rima glottidis to assume the form of a narrow V. N X is the right arytenoideus lateralis, the left being removed ; V *k* F is the left thyro-arytenoideus ; N *l*, N *l* is the crico-arytenoideus posticus ; B B are the crico-arytenoid ligaments.]

Thus the larynx is composed of four cartilages, and of three fibro-cartilages, which form its frame or skeleton. The cartilages are the *cricoid*, the *thyroid*, and the two *arytenoid*. The thyroid is articulated with the cricoid by the extremity of its inferior horns. During life the thyroid is fixed relatively to the cricoid cartilage, which is contrary to the received opinions on this subject. Each arytenoid cartilage is articulated with the cricoid, by means of an

* Carpenter.

oblong *facette*, and is concave transversely. The cricoid presents a *facette*, the disposition of which is analogous to that of the arytenoid cartilage, with this difference, that it is convex where the corresponding part of the other is concave. Near the articulation is found a synovial capsule closed anteriorly and posteriorly, but loose laterally. Before the articulation is the thyro-arytenoid ligament, and behind a strong ligamentous fasciculus, which may be called the crico-arytenoid ligament, from its attachments.

Arranged as I have now described, the articulation will only permit the arytenoid cartilages to move laterally upon the cricoid. All motion anteriorly and posteriorly is impossible, as well as a certain see-saw motion that is mentioned in books on anatomy, which cannot be produced by any muscle. This articulation must be considered as a simple lateral ginglymus. The fibro-cartilages of the larynx are the epiglottis, and two small bodies which are found above the upper part of the arytenoid cartilages, and which were called by Santorini *capitula cartilaginum arytenoidarum.*

A great number of muscles are attached mediately and immediately to the larynx. Some of these muscles have been called *extrinsic;* they are destined to move the organ as a whole, either to elevate or depress it, or to carry it backward or forward, &c. Besides these, the larynx has muscles, the use of which is to move one part upon another; these are called *intrinsic.* They are, 1st. The *crico-thyroid* muscles, the use of which is not to depress the thyroid upon the cricoid cartilage, as has been heretofore believed, but, on the contrary, it elevates the cricoid, making it approach the thyroid, or even causing it to pass a little under its inferior edge. 2d. The posterior *crico-arytenoid*, and the lateral *crico-arytenoid* muscles, the use of which is to carry the arytenoid cartilages outwardly, separating them from each other. 3d. The arytenoid muscle, which draws together and applies to each other the arytenoid cartilages. 4th. The *thyro-arytenoid*, which are the most important to be known of all the muscles of the larynx, inasmuch as their vibrations produce vocal sounds. These muscles form the lips of the glottis, the inferior, the superior, and lateral parietes of the ventricles of the larynx. 5th. Lastly, the muscles of the *epiglottis*, which are the *thyro-epiglottis*, and the *aryteno-epiglottis*, and some fibres which may be viewed as the *vestige* of the *glosso-epiglottis*, which exists in many animals. Contraction has an influence, therefore, on the position of the epiglottis.

The larynx is covered on its interior surface by a mucous membrane. This membrane, in passing from the epiglottis to the arytenoid and thyroid cartilages, forms two folds, which are called the *lateral ligaments of the epiglottis;* they run together to form the superior and inferior ligaments of the glottis. Behind and in the tissue of the epiglottis we find a great number of mucous follicles, and some mucous glands. There exists in the thickest part of the ligaments of the epiglottis, a collection of these bodies,

which have been improperly enough called the *arytenoid gland.* Between the epiglottis posteriorly, and the os hyoides and thyroid cartilage anteriorly, we find a considerable bundle of very elastic, fatty, cellular tissue, analogous to that which is found in the neighbourhood of certain joints. The use of this body has not yet been assigned. I conceive that it serves to facilitate the frequent gliding of the thyroid cartilage on the posterior face of the os hyoides, to keep the epiglottis separated superiorly from this bone, and, at the same time, to furnish an elastic support, which may favour the functions which this fibro-cartilage performs in the voice and deglutition.

The blood-vessels present nothing very remarkable. This remark, however, will not apply to the nerves of this organ; their distribution deserves to be examined with care. These nerves are four in number, viz., the superior laryngeals and the recurrents, or inferior laryngeals.

The recurrent nerve is distributed to the posterior crico-arytenoid, to the lateral crico-arytenoid, and to the thyro-arytenoid muscles; none of its ramifications are transmitted to the arytenoid, or the crico-thyroid muscles. The superior laryngeal nerve, on the contrary, is sent to the arytenoid muscle, to which it gives a considerable branch; and to the crico-thyroideus it sends a filament less remarkable for its size than the mode of its transmission. In some cases, however, this filament does not exist; but then the branch of the external laryngeal nerve is larger. The remainder of the filaments of the laryngeal nerve are distributed to the muscles of the epiglottis, and to the mucous membrane which covers the entrance of the larynx. This part is endued with excessive sensibility.

The name *glottis* is given to the opening between the thyro-arytenoid muscles and the arytenoid cartilages. In the dead body the glottis presents a longitudinal opening or chink, about eight lines long and two or three wide, and larger at the posterior than the anterior part, where the two sides approach, so as to touch at the point where they are inserted into the thyroid cartilage. The posterior extremity of the glottis is formed by the arytenoideus muscle.

When we bring the arytenoid cartilages together, so that their internal surfaces touch, the glottis is diminished about one third of its length; it then presents an opening not more than from one half to a line in width, and five or six lines in length. The sides of the rima are called the *lips of the glottis.* They present a sharp edge, directed upward and inward, and are principally formed by the thyro-arytenoideus muscle, and by the ligament of the same name, which covers, like an aponeurosis, the muscle to which it is strongly attached; and itself, covered by the mucous membrane, forms essentially the thin or cut edge of the lip. These lips of the glottis vibrate during the production of the voice, and may be considered as *the reed* of the instrument.

Above the inferior ligaments of the glottis are the ventricles of

the larynx, the cavity of which is more spacious than it seems to be at first, the external inferior and superior walls of which are formed by the thyro-arytenoideus muscle, turned upon itself; the extremity or anterior wall is formed by the thyroid cartilage. By means of these ventricles the lips of the glottis are perfectly insulated at their superior edge.

We see, above the opening of the ventricles, two bodies which have a great analogy in their arrangement with the vocal chords, and which form a second glottis above the first; these are called the *superior ligaments of the glottis.* They are formed by the superior edge of the thyro-arytenoid muscle, a little of the fatty, cellular tissue, and the mucous membrane of the larynx, which covers them before entering into the ventricles. Such are the observations which are easily made on the larynx in the dead body. I believe no one has ever examined the glottis in man during life; at least no one, to my knowledge, has ever written on the subject. When we examine it in living animals—dogs, for example—we find that it enlarges and diminishes alternately. The arytenoid cartilages are carried outward at the moment that the air penetrates into the lungs, and they approach and apply themselves to each other at the instant the air passes out from this cavity.

Mechanism of the Production of the Voice.

If we take the trachea and larynx of an animal or man, and blow strongly into the trachea, towards the larynx, no sound will be produced but a slight noise resulting from the friction of the air against the walls of the larynx, as will take place in any other elastic tube. The air passes through the whole extent of the glottis, the lips of which are separated and put slightly in motion by the current of air. If, continuing to blow, we bring together the arytenoid cartilages, so that their internal surfaces touch, there will be sometimes produced a disagreeable snoring sound, and sometimes, but more rarely, a sound having some analogy with the voice of the animal to which it belongs; but very often it is impossible to obtain the latter sound. The sound will be more or less acute or grave, according as the cartilages approach each other with more or less force; it will be more intense when we blow into the trachea with the most force. It is easy to see, by this experiment, that it is the inferior ligament of the glottis which, by its vibrations, produces the sound.

An opening made into the trachea in man and animals below the larynx deprives them of voice; this will be restored if the opening be stopped mechanically. I know a man who has been in this situation for many years; he can only speak when his cravat, which closes a fistulous opening in the larynx, is drawn tight. The same effect is produced when the larynx is opened below the inferior ligaments of the glottis.

On the contrary, should a wound exist above the glottis, affecting the epiglottis and its muscles, the superior ligaments of the glottis, or even the superior part of the arytenoid cartilages, the

voice will still remain. Indeed, when the glottis of a living animal is laid bare, when it cries out, it is easy to perceive that the voice is formed by the vibration of the *vocal chords.** M. Cagnard-Latour, one of our ingenious naturalists, has constructed a little apparatus, a true artificial larynx, consisting of two thin laminæ of gum elastic, stretched over the end of an open tube, touching each other at their edges. On blowing gently into the tube, a reeded motion is produced similar to that of the larynx, and, consequently, a sound very analogous to the voice. From this I think it is placed beyond a doubt, that the voice is produced in the glottis by the movements of its inferior ligaments. If this be considered as well established, can we, on philosophical principles, account for the formation of the voice? The following explanation appears to me the most probable. The air forced from the lungs passes at first into a large canal, which soon contracts, and it is then compelled to pass through a narrow passage or chink, the sides of which are two vibrating plates, which, like the plates in reeded instruments, transmit and intercept alternately the passage of the air, and cause, at the same time, sonorous undulations in the current of air which is transmitted.

But why then, it may be asked, when we blow strongly into the human trachea after death, is there no sound produced analogous to the human voice? Why is the paralysis of the *intrinsic muscles* of this organ always followed by the loss of voice? and why is an act of the will required for the formation of vocal sounds? The answer is easy. The ligaments of the glottis do not acquire the power of vibrating, like the plates in reeded instruments, except when the thyro-arytenoid muscles are contracted; of consequence, in all those cases where this is not the case, no voice will be produced.

Experiments upon animals perfectly agree with this doctrine. Divide the two recurrent nerves, which, as we have said before, are distributed to the thyro-arytenoid muscles, and the voice is immediately lost. Cut but one, and the voice is only half lost. I have, however, seen many animals utter very sharp cries, when they felt severe pain, after the recurrent nerves had been divided. But these cries were extremely analogous to sounds produced mechanically with the larynx of the animal after death, by blowing into the trachea, and, at the same time, approximating the arytenoid cartilages; a phenomenon which is readily explained by the distribution of the nerves of the larynx. The recurrents being divided, the thyro-arytenoid muscles cease to contract, and the result is aphonia. But the arytenoid muscle, which receives its nerves from the superior laryngeal, contracts itself, and, at the moment when a strong expiration takes place, one of the arytenoid cartilages being applied to the other, the rima glottidis is contracted, by which the thyro-arytenoid muscles are thrown into a state of vibration, though they are not contracted.†

* This is the name given by Ferrein to the lips of the glottis.

† Every reeded instrument has four parts: 1st, the reservoir of air; 2d, the *porte-vent*;

One of the most learned philosophers of our time, M. Savart, has inserted, in the fifth volume of my Journal of Physiology, a memoir on the comparison by me between the larynx and reeded instruments. The following is his principal objection. "It would be necessary," says he, "that the analogy be admissible, that the larynx should not produce any sound while the inferior vocal ligaments were apart from each other." Now it is precisely this which experiment proves. When we blow into a larynx of which the edges of the glottis are separated, there is not produced any vocal sound. To obtain a noise that approaches it, it is necessary to make the vocal ligaments touch. Besides, observe the glottis of a dog at the moment when its voice is produced, and you will immediately convince yourself that the sound is formed at the moment when the lips touch and separate rapidly.

"An important objection," adds M. Savart, "that may be made to those who pretend that the voice is produced by a mechanism analogous to the reed, is, that the quality of the sound of the human voice is very different from that of reeded instruments, however perfect we may suppose them. The sounds of the voice have a character which no musical instrument can imitate; this must necessarily be the case, for they are produced by a mechanism founded on principles which do not serve as the bases of any instruments."

I admit, with M. Savart, that art has not yet succeeded in completely reproducing the human voice; and this must be, for a reed has not yet been invented which can assume, in an instant, a hundred different physical characters, and form a hundred shades of tone, note, and intensity of sound. We must, however, render this justice to artists who have attempted to imitate the human voice, that many have approached it, and, what is not indifferent to this question, it has always been by means of reeds.

After having endeavoured to destroy the analogy I had endeavoured to trace between the larynx and the reed, M. Savart proposes to compare the organ of the voice to a small whistle used by hunters to imitate the voice of certain birds. It is a kind of hemispherical instrument of some lines in diameter, and pierced at two points opposite to two chinks, into which the air is forced after the instrument has been placed in the mouth. The learned philosopher supports his opinion by numerous facts, experiments, and interesting considerations, which, no one can doubt, have enlarged the field of acoustic knowledge. But I have not been able to recognise the resemblance which he has endeavoured to establish between a *reclame* and the larynx. This instrument produces sound, its edges being separate and immovable, while that of the voice is formed, the lips of the glottis being movable and in con-

3d, the reed; 4th, the tube, or *porte-voix*. These four parts exist in the vocal apparatus. The lungs and bronchiæ are the reservoir of air; the trachea, the *porte-vent;* the larynx, the reed; the pharynx, mouth, and nasal cavities, the *porte-voix*. The similitude is complete.

tact. Some physiological facts that I shall soon refer to will confirm, if necessary, the refutation of this theory, so ingenious and learned.

The vocal sound, after being thus formed in the glottis, passes into the tube or *porte-voix*, which is represented by the pharynx and mouth, and sometimes the pharynx and nasal cavities. In its course, the voice is more or less modified, according to the form and length of the tube that it traverses. These modifications are not very different from those which are observed in reeded instruments. If, for example, the sound is loud, the mouth is opened widely, and represents a conical *porte-voix*, favourable, as every one knows, to the transmission of intense sounds.

Thus far, the analogy, or rather similitude, between the organ of the voice and reeded instruments in general, is evident. But it ought to be more particularly confined to those which are played by the breath of the artist. In fact, the air which throws into a state of vibration the reed is not a pure and cold air, as in organs, but air mixed with carbonic acid and the vapour of water; besides, the air is of a temperature which approaches to that of the lungs. Now it is known in physics, that the nature of the sonorous gas, its density, &c., influence the quality of sounds; it is the same as respects the mixture of gas and vapours.

Intensity or Volume of the Voice.

This depends, like all other sounds, on the extent of the vibrations.* The greater the force with which the air is expelled from the chest, the greater will be the extent of the vibrations of the vocal chords; and the longer these chords are, that is, the greater the capacity of the larynx, the more considerable will be the extent of the vibrations. A strong person, whose chest is capacious, and in whom the dimensions of the larynx are considerable, presents those circumstances which are the most favourable to intensity of the voice. But when this person becomes sick, and his strength reduced, his voice loses much of its intensity; for this simple reason, that it can no longer expel the air from the chest with great force.

Children, women, and eunuchs, in whom the larynx is proportionally smaller than in the adult man, have also naturally the voice much less intense than his.

The ordinary production of the voice results from simultaneneous movements of both sides of the glottis. If one of these sides loses the faculty of exciting vibrations in the air, the voice will necessarily lose the half of its intensity, supposing the expiratory force to remain the same. We may satisfy ourselves on this point by dividing one of the recurrent nerves of a dog, or by examining the voice of a person attacked with complete hemiplegia.

* Probably the intensity of sound depends upon other causes besides the extent of the vibrations; and it must be the same with the intensity of the voice.

Timbre of the Voice.

Each individual possesses a peculiar *timbre* or tone of voice by which he is known; the different ages and sexes are marked in this manner. The *timbre* of the voice, then, presents infinite modifications. We are ignorant of the precise physical circumstances on which this depends; the female tone, however, and that which is observed in children and eunuchs, is generally found connected with a peculiarly soft state of the cartilages of the larynx and small size of the organ. The masculine tone of voice which is sometimes observed in females, on the contrary, seems to be connected with an osseous state of these cartilages, particularly the thyroid.

Timbre, then, is a modification of sound, of which no very satisfactory account has yet been given.

Of the different Notes or Extent of the Voice.

The sounds which the larynx in man is capable of producing are extremely numerous. Many distinguished authors have endeavoured to explain their formation, but these, when examined, will be found to be rather comparisons than explanations. Thus, Ferrein considered the ligaments of the glottis as chords, and he explained the different notes of the voice by the different degrees of tension of which he supposed they were capable, &c.; others have compared the larynx to a wind instrument, to the lips of the horn, or to the human lips in the act of whistling. But all the explanations which have heretofore been given err radically in this, that they are founded upon a consideration of this organ in the dead body, while the only true mode of investigating the subject is a minute attention to the anatomy of the part, and a careful examination of the phenomena exhibited during life. I have endeavoured to supply this deficiency, and will now state the results which I have obtained.

I laid bare the glottis of a dog, making an incision between the os hyoides and thyroid cartilage, and examined the part carefully while he was howling. I found, when the sounds were grave, that the ligaments of the glottis vibrated through their whole length, and that the expired air passed out through the whole extent of the glottis. When the sounds were acute, the ligaments did not vibrate at their anterior, but only at their posterior part, the air only passing through that portion of the glottis which vibrated, the opening, of course, being diminished. When the sounds became very acute, the ligaments no longer vibrated, except at the arytenoid extremity; and the expired air then passed out at this portion of the glottis. It appeared that the acuteness of the sound increased until the glottis became entirely closed, when the air could no longer pass through the larynx, and the sound ceased. The principal use of the arytenoideus muscle being to close the glottis at its posterior extremity, it must be the chief agent in producing acute sounds. I was desirous of knowing what effect would be produced upon the voice by the division of the two laryngeal nerves which

supply this muscle. I had recourse to some experiments for this purpose, and found that when this was done, the voice of the animal lost all its acute sounds; and that it likewise acquired an habitual gravity, which it had not before possessed.

The structure of the larynx in man and in the dog is so much alike, that we cannot doubt that the same phenomena take place in both. There is one circumstance which must have a certain influence on the notes of the voice; it is the contraction of the thyro-arytenoid muscles. The more strongly these muscles contract, the more will their elasticity be increased, and the more susceptible they will become of vibrating rapidly, and of producing acute sounds; on the contrary, the less they are contracted, the more grave the sounds will be. We may also presume that the contraction of these muscles concurs powerfully in closing the glottis, particularly its anterior half.

The artificial larynx of M. C. Latour demonstrates physically the two physiological phenomena of which I spoke, as respects the different notes of the voice. If you blow into the tube, the elastic plates vibrate through their whole length; the sound is then grave. If you shorten the plates, the sound becomes acute in the same proportion, but when they are reduced to four lines there is no sound; while in the living larnyx I have observed the sound to be formed, though the opening was not to the extent more than two lines. But however this may be, the shorter the opening in the larynx through which the air escapes, the more acute is the sound. The second phenomenon, arising from the tension of the vocal ligaments, is easy to see in the same instrument, for, by varying the tension of the plates, the notes rise or fall.

It would appear, then, that the larynx represents a reeded instrument with a double plate, the notes of which are more acute as the plates are shortened, and more grave as they are elongated. But although the analogy be generally just, it does not necessarily follow that it is in every respect complete. In fact, the common reeds are composed of rectangular plates, fixed on one side, and free on the other three; in the larynx the vibrating plates are nearly rectangular, but they are fixed by three sides instead of one. Again, we raise or fall the notes in the common reeded instrument by varying its length; in the plates of the larynx it is the size which varies. Lastly, in musical instruments we cannot employ reeds the plates of which can, every instant, alter their thickness and elasticity, as happens in the ligaments of the glottis. From what has been said, it can easily be conceived that the larynx may produce the voice and vary its notes, somewhat after the manner of reeded instruments, without our undertaking minutely to explain all the particularities in its mode of action.

It has heretofore been believed that the tube which conveys the air to the reed has no influence on the sound produced. M. Biot relates an experiment of M. Greniè, which proves the reverse of this. It is not impossible that the lengthening or shortening of

the trachea, which is the tube for conveying the air to the larynx, may have some influence in the production of the voice, and on its different tones.

Having examined the *reed* of the organ of voice, it will now be proper to consider the tube which the vocal sound traverses, after having been produced. In proceeding from below upward, the tube is composed, first, of the interval comprehended between the epiglottis before, and the lateral ligaments on the sides, and the posterior walls of the pharynx; second, of the pharynx, posteriorly and laterally, and of the most posterior part of the base of the tongue, anteriorly; third, sometimes of the mouth, sometimes of the nasal cavities, and at other times of both.

This tube may be elongated or shortened, enlarged or diminished; being susceptible of assuming an infinite number of different forms, it will fulfil very well the office of the body of a reed instrument; that is, it will possess the power of arranging itself so as to harmonize with the larynx, and thus favour the production of all the numerous notes of which the voice is susceptible. It will increase the intensity of the vocal sounds by assuming a conical form; by enlarging externally, it will give them an agreeable rotundity; or by arranging the external opening conveniently, it will nearly suppress them, &c.

Until natural philosophy has determined with precision the influence of the tube in reeded instruments, we can, at best, only form probable conjectures respecting the influence of the tube in the formation of the voice. We can only illustrate this point by a small number of experiments which relate to those phenomena which are the most apparent.

The larynx elevates itself during the production of acute sounds, and is depressed when they are grave; of consequence, the vocal tube is shortened in the first case, and elongated in the second. We may conceive that a short tube is most favourable to the transmission of acute sounds, and that a long one is most advantageous in those which are grave. At the same time that the tube changes its length, it likewise alters its size; a circumstance which is remarkable, because, as we have seen above, the size of the tube influences its facility of transmitting sound.

When the larynx descends, that is, when the vocal tube is elongated, the thyroid cartilage is depressed, and separated from the os hyoides to the whole extent of the thyro-hyoidian membrane. By this separation the gland of the epiglottis is carried forward, and comes to lodge itself in the concavity of the posterior face of the os hyoides; this gland necessarily draws after it the epiglottis, from which results a considerable enlargement of the inferior part of the vocal tube.

The opposite phenomenon happens when the larynx is elevated. We then see the thyroid cartilage raise itself behind the os hyoides,* displacing and pushing backward the gland of the

* The thyro-hyoidian muscles appear more particularly destined to produce the movement, by which the thyroid cartilage passes behind the os hyoides.

epiglottis; this pushes the epiglottis in its turn, so that the vocal tube becomes thus very much contracted. In imitating this movement upon the dead body, we may satisfy ourselves that this contraction may be carried to five sixths of the size of the tube. Now we adapt a large tube to a reed which is to form grave sounds, and, on the contrary, a narrow tube to one which is intended to convey acute sounds. We can then, to a certain extent, account for the changes of size which take place in the vocal tube.

The presence of the ventricles of the larynx, immediately above the inferior ligaments of the glottis, appears to be intended to insulate those ligaments, so that they may vibrate freely. When foreign bodies are introduced into these ventricles, or when they are covered with a tenacious mucous, or a false membrane, the voice is either entirely lost, or very much weakened.

But these cavities are not indispensable to the production of the voice; many animals whose vocal sounds are very intense are destitute of them: they may be destroyed in a dog, as was done by Bichat, without causing loss of the voice.

From its form, position, elasticity, and the movements impressed upon it by its muscles, the epiglottis seems to constitute an essential part of the apparatus of the voice. But we may inquire, What are its uses? We have seen already that it assists powerfully in the contraction of the vocal tube, but we may suppose that it performs a still more important function.

M. Grenié, who has invented so many ingenious and useful modifications of reeded instruments, did not arrive at these results by a single effort, but had to pass through a long series of intermediate inquiries. At one period of his investigations he wished to augment the intensity of the sound without changing the reed. To effect this, he was obliged to augment, gradually, the intensity of the current of air; but this, though it rendered the sounds stronger, had likewise the effect of elevating the note. To remedy this inconvenience, M. Grenié could find no other method than to place obliquely in the tube, immediately above the reed, a flexible, elastic tongue, resembling very much the epiglottis: we may suppose from this that the epiglottis assists in giving to man the power of swelling vocal sounds, without elevating the note.

The intensity of the voice is evidently influenced by the vocal tube. The most intense sounds that the voice can produce require that the mouth should be opened widely, the tongue a little drawn back, the veil of the palate raised up, closing all communication with the nasal fossæ. In this case the pharynx and the mouth evidently perform the office, and resemble, with considerable exactness, those tubes of reeded instruments which enlarge at the part where the air passes out, and the effect of which is to augment the intensity of the sound produced by the reed. If the mouth be partly closed, the lips projected forward, and more or less drawn together, the voice will acquire an agreeable rotundity, but will lose its intensity. This result is easily explained by what has been before said of the influence which the form of the

tube exerts in reeded instruments. For the same reasons, every time the vocal sound passes the nasal fossæ, it becomes weaker, because the form of these cavities is extremely well adapted to diminish the intensity of sounds.

If the mouth and nose are closed, and prevent the passage of the expired air, the vocal sound is formed in the larynx, but it does not continue long: its limits are fixed by the small quantity of air that may be contained in the mouth and the nasal cavities. As soon as these cavities are filled and distended, the vocal sound ceases. In such case the sound is weak and stifled, as might be supposed, inasmuch as it can only reach the ear through the parietes of the mouth and nose.

It appears from the recent observations of Dr. Bennati, that the veil of the palate and the uvula undergo remarkable modifications during the production of acute and grave sounds. In the formation of the latter, the veil is horizontal, large, and stretched, the uvula pendant and vertical. In proportion as the sounds are raised, the veil falls, the cavity of the pharynx diminishes, and the uvula becomes shorter. Lastly, in the most acute sounds, the veil of the palate grows still narrower, and the uvula entirely disappears. M. Bennati attached so much importance to these latter modifications of the vocal tube, that he named the acute sounds *supra-laryngeal*, intending to indicate by that epithet that the pharynx, the veil of the palate, &c., are the essential parts in their production. We cannot, however, admit this opinion, though most anxious to render justice to the learned Italian; but we do not see thus far that the phenomena coincide with the production of acute or grave sounds.

We have already seen, in speaking of the production of the voice, that a great number of modifications in the *timbre* arise from the changes which take place in the thickness and elasticity of the lips of the glottis. The tube also produces a great number of other modifications, varying according to its length and capacity; the form and contraction of the pharynx, the position of the tongue, and the veil of the palate; according as the sound passes out, either entirely through the mouth or nose, or by these two cavities at the same time; the form of the mouth and nose of the individual, the presence or absence of the teeth, the volume of the tongue, &c. The *timbre* of the voice, I say, will bemodified by all these circumstances. Whenever, for example, the sound traverses the nasal fossæ, the tone will be disagreeable, or, as it is commonly called, *nasal*. Persons who think that the nasal cavities can augment the intensity of vocal sounds by resounding through them, deceive themselves, as these cavities can only produce the reverse effect; also, whenever, from any cause, the sound is introduced into them, the voice becomes dull or nasal.

The sonorous undulations developed by the vibrations of the laryngeal reed are transmitted not only to the column of air which traverses the pharynx and mouth, but extend to that contained in the nasal cavities, through the membranous and osseous

palate. They are also propagated in the opposite direction into the gaseous mass that fills the chest, or, more properly, the lungs, by which the tone and intensity of the voice are modified.

The *ressonnance* of the chest is regarded at the present day as a most interesting phenomenon to the physician, in consequence of the numerous modifications that it undergoes during disease.

Independently of the numerous modifications that the tube of the vocal organ determines in the intensity and tone of the voice, in permitting and intercepting alternately its production, it also produces another most important modification. By this the vocal sound is divided into small portions, each of which have a distinct character, each being produced by a particular movement of the tube. This peculiar influence of the vocal tube is called the *faculty of articulation*, which presents an infinite number of individual differences in connexion with the organization peculiar to the vocal tube.

Thus far we have treated of the human voice in a general manner; we shall now speak of its principal modifications, viz., the *cry*, or *native voice;* the *voice*, properly so called, or the *acquired voice; speech*, or *articulate voice;* singing, or *appreciable voice.*

Of the Native Voice, or Cries.

This is an appreciable sound, which, like all others produced by the larynx, is susceptible of variety, both in *timbre*, intensity, and note. A cry is easily distinguished from all other vocal sounds; but, as its character depends upon its *timbre*, it is impossible to explain, physically, the reason of the difference between other vocal sounds and it.

In whatever condition man may be found, he is always capable of uttering this sound. The new-born infant and the decrepit old man, the savage and the civilized man, those who have been dumb from their birth, and idiots, are all capable of uttering cries. We must consider, therefore, crying as essentially depending upon organization; this will be still more apparent from examining its uses.

By a cry we express vivid sensations, whether they arise from within or without, whether they are agreeable or painful. By cries we express our most simple, instinctive wants, and natural passions. There are cries of joy and pain, of anger, and of fear, &c. The social wants and passions not being indispensably connected with the organization, but requiring a state of civilization to develop them, have no peculiar cries.

Cries generally include the most intense sounds that the organ of the voice is capable of forming. Most frequently the *timbre* wounds the ear, and acts strongly upon those who are exposed to its effects. These establish important relations between man and his fellow-creatures. A cry of joy imparts pleasure, a cry of grief excites pity, and the cry excited by fear carries terror to a distance, &c. This kind of language is found among most ani-

mals, and is, in fact, nearly the only one they possess. The singing of birds can only be considered as a modification of their cries.

Of Acquired Voice.

Man in his ordinary condition, that is, in a state of society, and when he is endowed with the sense of hearing, soon perceives, even in his early infancy, that his fellow-creatures produce sounds which are not cries. Having remarked this, by the instinctive force of imitation, he is soon able to form analogous sounds; this we call an *acquired voice.* A deaf child cannot make these remarks; he, therefore, can never acquire the power of making this sort of sounds.

The voice does not appear to differ from cries, except in intensity and *timbre*, for it is formed of unappreciable sounds, of which the ear cannot distinguish accurately the intervals.

Inasmuch as the voice is the result of hearing and of an intellectual effort, it cannot be developed unless both these conditions exist. Children who are deaf from birth cannot form any idea of sound; and idiots are not capable of establishing any relation between sounds which they hear, and those which they are capable of producing; they have, therefore, no voice; although the vocal apparatus in both may be fitted to form and modify sounds, as well as in those of individuals whose conformation is the most perfect. For the same reasons, those individuals who have been very improperly called savages, from their having wandered alone in the forest from their infancy, do not possess voice, because the understanding does not sufficiently develop itself in this insulated state, and no necessity for mental exertion exists.

The *timbre*, intensity, and notes of the voice are all susceptible of numerous modifications by the action of the larynx; the vocal tube also exerts a powerful influence upon the voice. Speech and singing are but modifications of the acquired voice.

It is difficult, perhaps impossible, to say how man has reached that degree of perfection by which he is enabled to represent his intellectual operations by modifications of the voice, to compose languages, and especially to invent the alphabet. These inquiries are undoubtedly curious and useful, but not indispensable, and, besides, do not properly belong to physiology; it is the mechanism of language which alone concerns us.

Language is composed of words, which are the signs of our ideas; and words are formed by the letters or sounds of the alphabet, which are for the most part but modifications of the voice. Grammarians distinguish letters into vowels and consonants; but this is not a proper physiological distinction. *We* may distinguish them into those which are true modifications of the voice, and those which are formed independently of the voice.

The letters which are formed by the voice in the languages of Europe are, *a*, as it is pronounced in English in the word *hall;* (French) in *â* in *hâle*, and *a*, *è*, *é*, *e*, French mutes; *i*, *o*, Italian;

o, *e*, *u*, *eu*, in French; and *u* in Italian. Each of these letters may be modified; this we express when we say that it is long or short. These are the vowels of grammarians. The other vocal letters are, *b* and *p* (*labial consonants*), *d* and *t* (*dental consonants*), *l* (*palatal consonant*), *g* and *k* (*guttural consonants*), *m* and *n* (*nasal consonants*).

The formation of the vowels requiring the vocal tube to be open depends upon the form it affects at the time the voice is produced. The vocal consonants suppose that the tube is closed, and result from the manner of its being opened at the moment the voice is formed. The existence of these last letters is, then, instantaneous.

The other letters, *f* and *v*, the two sounds of *th*, in English; *s*, *z*, *ch*, *j*, *r*, *h*, and *x*, in Spanish, and χ in Greek.

These letters are produced by the friction of the air against the walls of the mouth, and are, of consequence, independent of vocal sounds, and may be prolonged as long as the air continues to pass out from the lungs.

Each letter, both vowels and consonants, is produced by a certain disposition or particular movement of the vocal tube. The tongue is the principal agent in the formation of some; in others, the lips or teeth; and in others the sound traverses the nasal fossæ, &c.

In order that the pronunciation may be correct, it is necessary that the vocal tube should be well formed. When there is any lesion of this part, *e. g.*, a perforation of the vault of the mouth, or of the *uvula* or veil of the palate, a loss of the teeth, or a swelling or paralysis of the tongue, the power of articulation becomes altered, and may be even lost.

The simple noise made by the air in traversing the larynx may be sufficient for pronunciation, as happens when we speak very low. Persons who have completely lost their voice still continue to pronounce with so much distinctness as to be understood at a certain distance.

We are indebted to M. Deleau for a curious experiment on this point. By means of a curved tube, introduced through one of the nostrils into the back part of the mouth, he forced in a current of air, by means of a reservoir in which it was condensed. This current of air, in passing through the elastic tube, developed a slight sound, which, traversing the vocal tube, like the voice, could be articulated and serve as a language; the more singular, as it was formed at the same time as the ordinary speech. In this case, the person subjected to the experiment formed simultaneously two words, which, articulated at the same moment and in the same manner, produced upon the auditors a most singular impression. There is some analogy between this experiment and the case of a convict in the Bagnio at Toulon, whose glottis was obliterated in an attempt to commit suicide, and who breathed by a fistulous opening of the trachea. This man, who could not produce any sound by his larynx, as the air did not traverse this

organ, had succeeded in forming in the back part of his mouth a small reservoir of air, with which he found means to produce a certain noise. This noise, subjected afterward to the organs of pronunciation, became at last a sort of speech, very limited, it is true, but which, nevertheless, enabled the unhappy convict to make known his principal wants.

By different combinations of letters we form sounds, more or less compounded, which are words. The formation of words is different in different languages. In the North of Europe the consonants are numerous, and the words are rough and difficult to pronounce, though this is not, perhaps, the true cause of it. In the South the vowels are most numerous, and the sounds are generally soft and harmonious.

The same sound is not always continued in the pronunciation of words. In articulating, the voice is raised and lowered, and its intensity and timbre varied in a manner which varies in every language. The mode of these variations constitutes *accent*, or the pronunciation peculiar to each country.

To articulate, or pronounce, is not to speak. A bird may be taught to *pronounce* words, or even sentences, but not to speak. Man is alone endowed with the faculty of speech, which is the most powerful means of expressing his intelligence; he alone attaches a meaning to the words which he pronounces, and to the arrangement which he gives them. He would, therefore, not possess speech unless he had understanding. In fact, the greater number of idiots never speak; they articulate sounds vaguely, but do not, and cannot attach any meaning to them.*

Of Singing.

The voice in singing differs from other sounds produced by the larynx, in this, that it is formed of appreciable sounds, of which the ear distinguishes easily the intervals, and perceives their agreement. These characters do not exist either in cries or in speech the intervals of which are inappreciable. Dodart has asserted that, in singing, the larynx undergoes an oscillatory movement from below upward; but his assertion is not confirmed by observation. We are ignorant of the precise conditions of the ligaments of the glottis and the rest of the vocal apparatus when arranged to form appreciable sounds. As respects each musical note, taken separately, it does not differ, physically, from the spoken voice, except by its extent. The true difference between singing and the other vocal sounds is fouud in the regularity and harmony of its intervals.

We remark very important differences among individuals in the extent, intensity, and note of the voice in singing. In a common voice there are about nine notes between its highest and its lowest notes; the most extensive voice does not much exceed two octaves in full and well-formed sounds.

There have been, and, indeed, still exist, a few individuals so happily organized that they can compass more than three oc-

* See Pinel on Insanity.

taves. Their vocal organs represent nearly the whole possible extent of the human voice. But these are extremely rare exceptions to the general rule.

There are two sorts of voices, the grave and the acute. They differ from each other by about one octave. In general, men have grave voices; those whose voice is the most grave may form acute sounds by taking what is called the *falsetto.* Women, children, and eunuchs are generally found to possess acute voices. By adding all the notes of an acute to those of a grave voice, they extend to nearly three octaves and a half.

The series of sounds in singing are composed of two distinct classes: the grave and medium sounds, which are made and sustained without effort; and the acute sounds, which in general require a contraction, more or less fatiguing, of the larynx or the muscles of the vocal tube, and particularly of the pharynx, veil of the palate, and of the tongue.

These two kinds of sounds differ to such a degree, as regards their physical character, that they appear to be produced by dissimilar instruments. The first are named *notes of the chest*, or *sounds of the first register ;* the second, *voice of the head*, or *falsetto, sounds of the second régister.* Dr. Bennati, of whom I have already spoken, has proposed recently to call the first sound *laryngeal*, and the second *supra-laryngeal.* I do not approve entirely of these names, as they may lead to an error, by inducing the belief that the grave and medium notes only are formed by the larynx, and that the higher notes are produced by the parts situated above the larynx, while, in fact, all the sounds of the voice result equally from the whole vocal instrument; only, like other wind instruments, it is arranged differently when it produces acute or imparts grave sounds.

It is certain that at the moment a singer passes from the first to the second register, he always makes a remarkable change in the larynx, the back part of the mouth, and the position of the tongue. We are unacquainted with the precise state of the glottis; we only know that it is soon attended with a sensation of fatigue. With respect to what takes place in the pharynx, the veil of the palate, and the tongue, it is apparent that all the muscles of these parts are thrown into great activity, varying in individuals, but the general effects of which are to retract the throat, stretch the veil of the palate, contract the uvula, &c. But the most attentive study of these phenomena throw no light on the physical nature of the sounds which constitute the falsetto. This point of physiological physics remains at present entirely unknown. I may say, however, that in making experiments with the artificial larynx of M. Latour, by stretching forcibly the laminæ or plates of elastic gum, I have frequently succeeded in forming sounds which, in comparison with the ordinary sounds of the instrument, were nearly the same as the falsetto to the sounds of the chest. This seems to indicate, what is in other respects very probable, that the larynx is

the principal agent in the formation of the sound, the other parts of the tube being accessories more or less indispensable.

We may add, that women, children, and eunuchs, whose voice is composed almost entirely of the sounds of the second register, and who require but little effort to produce them, have the larynx less voluminous than the adult man, this organ being quite cartilaginous.

The grave sounds, which are formed by a long glottis, and which, consequently, require a great expense of expired air, cannot be continued as long as the acute sounds, which, being produced by a narrow glottis, almost closed, require a much less expenditure of air; the difference in this respect may be as one to three.

For the same reason, we can continue for a much longer time a weak than an intense sound; and thus to know how to manage the breath is a very important part of the art of the singer. The more capacious the chest, the more air it will contain, and the easier it will be to produce those effects which astonish and delight us.

But the differences which exist between different voices do not alone regard extent. There are *strong voices*, the sounds of which are strong and noisy; there are *soft voices*, the sounds of which are sweet, and like those of the flute; *fine voices*, the sounds of which are full and harmonious; *just*, *false*, *flexible*, *light*, *hard*, and *heavy voices*. Some have their good sounds irregularly distributed, some in their *base*, some in their *treble*, others between.

Singing, like speech, is an effect of a state of society; it supposes the existence of hearing and intelligence. It is, in general, employed to paint our instinctive wants, passions, and different states of mind; joy, sadness, successful or unsuccessful love, have each their peculiar songs.

Singing may also be articulate. Then, instead of expressing simply sentiments, it becomes the means of expressing a great number of the acts of the understanding, but particularly of those which are connected with the social passions.

Declamation is a particular sort of singing, though the intervals of the tones are not entirely harmonious, nor are the tones themselves completely appreciable. It appears that among the ancients declamation differed much less from singing than among the moderns. It was probably analogous to what is called the *recitative* in modern operas.

The languages in the South of Europe, which are strongly accentuated, that is, vary their tones very much in simple pronunciation, are very suitable for singing.

All the modifications of the voice which we have examined are produced by the air passing out from the chest. The voice may also be formed at the moment the air traverses the larynx to penetrate into the trachea. But this *inspiratory voice* is hoarse, unequal, and of small extent; we cannot, but with difficulty, vary the tones; in a word, from the very character of the phenomenon, we can perceive that it does not pass according to the ordinary laws

of the animal economy. We can both speak and sing during inspiration. We are ignorant of the modification which the lips of the glottis undergo in the production of *inspiratory voice.*

The Art of Ventriloquism.

Inasmuch as man possesses the power of varying indefinitely the appreciable and unappreciable sounds of his voice, and can change at pleasure, in a thousand ways, its intensity and note, nothing can be easier than to imitate exactly the different sounds which strike upon his ear; this, in fact, he executes under a variety of circumstances.

Many persons imitate perfectly the voice and pronunciation of others; hunters imitate the different cries of their game, and succeed, by these means, in attracting them into their snares. The faculty which some persons possess of imitating different sounds, has been made a profession of by some individuals, who have been supposed to have received from nature an organization different from other men, and are called *ventriloquists.* But this is a mistake; they only possess the organs of speech and voice well arranged, so that they can readily execute the sounds which they wish to produce.

The principles on which this art rests are easy to comprehend. We know from experience that sounds are altered by a variety of circumstances, *e. g.*, that they become weakened, less distinct, and change their tone when they are at a distance from us. When a man descends into a well, and speaks to those who are above him, his voice does not arrive at their ears until it has undergone several modifications, arising from distance and the form of the canal which it has passed through. If, then, a person has carefully remarked these modifications, and exerts himself to imitate them, after a little practice he will be able to produce this acoustic illusion; and we can no more avoid being deceived by it, than we can prevent our seeing objects larger than they actually are, when we examine them through a magnifying glass. The deception will be complete, if he employ other illusions to distract the attention.

The better the talent of the artist, the more perfect and numerous the illusions will be; but we must guard ourselves from supposing that the ventriloquist* produces voice and articulate sounds differently from other persons. His voice is formed in the common manner, but it is modified by the artist in its volume and tone. As relates to his pronouncing words without moving his lips, it is because he employs words in which there are no labial consonants, which unavoidably require the motion of the lips to perform them. In one respect we may say, that this art is to the ear, what painting is to the eye.

* The term ventriloquist, and other words of a similar import, were employed in the infancy of science, but it is evident that we ought not to admit them now in scientific language.

Modification of the Voice by Age.

The larynx is proportionally very small in the fœtus and the newborn infant; its small volume is contrasted with the os hyoides, the tongue, and other organs of deglutition, which are very much developed; it is rounded, and the thyroid cartilage does not project from the neck. The lips of the glottis, the ventricles, and the superior ligaments are very short, in proportion to what they afterward become, for the thyroid cartilage being but little developed, the space which they occupy is necessarily inconsiderable. The cartilages are also flexible, and are far from possessing the consistence which they afterward acquire.

The larynx preserves these characters until about the period of puberty; at this time a general revolution takes place in the animal economy. The evolution of the genital organs determines a rapid increase in the nutrition of many of the other organs, especially that of the voice. The great increase in the nutritive powers is first apparent in the muscles; afterward, but more slowly, it is manifested in the cartilages, when the general form of the larynx becomes modified. The thyroid cartilage develops itself at its anterior part, and projects from the neck, but much more strongly in the male than in the female. From this circumstance results a considerable elongation of the lips of the glottis, or of the thyro-arytenoid muscles. This circumstance is much more worthy of remark than the general enlargement of the glottis, which takes place at the same time. These changes in the larynx, though rapid, are not sudden: they require six or eight months before they are finished.

After the age of puberty, the larynx undergoes no other very remarkable change, except that its volume somewhat increases, and the projection of the thyroid cartilage becomes rather more prominent. In man, the cartilages ossify partially; in old age this process continues, and at last becomes nearly complete; the gland of the epiglottis decreases, and the intrinsic muscles, especially those which form the lips of the glottis, diminish in size, become less deep coloured, lose their elasticity, and at last undergo modifications similar to those of the rest of the muscular system.

The production of the voice being dependant upon the passing of air into the chest, and the fœtus being plunged in the fluid of the amnios, it is, of course, incapable of forming sounds: but at the moment of its birth, the infant produces sharp and intense sounds. *Vagitus* is the name which has been given to this cry of infants, by which it expresses its wants and feelings; we may recollect that this is the object of its cries. Before the end of the first year, the infant begins to form sounds different from crying. These sounds are at first vague and irregular, but they soon become more and more distinct; at this time nurses begin to teach them to pronounce the most simple, and at last the most complicated words.

The pronunciation of children is different from that of adults; this is owing to the great difference which exists in the structure of their organs. In children, the teeth are still concealed in the alveolar processes; the tongue is comparatively large; the lips project more than is necessary to cover the anterior part of the jaws when they are brought in contact, and the nasal cavities are but little developed.

By degrees, and in proportion as the organs of pronunciation approximate those of the adult, children articulate distinctly the different combinations of letters. They do not learn to form appreciable sounds, or to sing, for the most part, until long after they have acquired the faculty of speech. These different sounds are what we have called the *acquired voice*, and are never formed by the child when it is deaf; the sounds it utters can only be considered a modification of the *vagitus*. Until the age of puberty, the larynx and lips of the glottis remain proportionally very small, and the voice is entirely composed of sounds which are acute. It is then physically impossible for the larynx to produce grave sounds.

At the age of puberty, particularly in men, the voice undergoes a remarkable modification. It acquires in a few days, sometimes very suddenly, a grave note, essentially different from what it exhibited before; it falls generally an octave. In some cases the voice is nearly lost, and does not entirely return for some weeks; frequently there remains for a time a remarkable hoarseness: young men often form very acute sounds when they intend to produce those which are grave. It is therefore, at this time, impossible for them to produce appreciable sounds, or to sing.

This state of things continues frequently for a year, after which the voice gets its natural note, which remains during life; but we sometimes meet with individuals who, at this time, lose forever the faculty of singing. and others, whose voices before this pepiod were rich and extensive, afterward become indifferent and limited.

The gravity which the voice acquires depends, evidently, on the development of the larynx, and especially on the elongation of the lips of the glottis. As these parts cannot extend posteriorly, they are lengthened anteriorly; at this period, also, the larynx becomes prominent, forming what is called the *pomum Adami*. In females, the larynx does not undergo this increase of size; the voice, therefore, generally remains acute.

The voice preserves nearly the same characters from puberty until the approach of old age; at least its modifications, during this interval, are inconsiderable, and chiefly respect its *timbre* and volume. But as old age approaches, the voice becomes essentially altered, its *timbre* is changed, and its extent diminished; and singing is more difficult, the sounds resembling cries, and being produced with difficulty and fatigue. The organs of pronunciation are altered, the teeth being shorter and often lost. All these phenomena become more remarkable as old age advances, the

voice becoming weak, tremulous, and broken. The same remarks apply to singing; the defects in both cases arising from the imperfection in the muscular contraction of the parts, the slowness in the movements of the tongue, the loss of the teeth, and the proportionally increased length of the lips, &c., all of which must necessarily have a strong influence on the pronunciation.

Relations between Hearing and Voice.

We have already spoken of the connexion between hearing and voice. It is such, that an infant deaf from its birth is necessarily dumb; that a person who has a false ear has necessarily a false voice; that an individual whose hearing is imperfect is instinctively induced to talk loud or low. But the larynx in those who have been deaf from birth is by no means incapable of producing voice; it has been before observed that they utter cries. Of late, by different processes, persons deaf and dumb from their birth have been taught to speak, so as to maintain a conversation; but their voice is hoarse, rough, and unequal. I believe, however, that there has been no instance where a deaf and dumb person has been taught to sing.

There have been some instances of persons who have acquired hearing at an age when they could give an account of their sensations. Among all, the voice has been developed soon after the individual has acquired the sense of hearing.

The *Memoirs of the Academy of Sciences* for the year 1703 contain an example of this, which occurred in a young man of Chartres, who was twenty years of age, "who, to the great astonishment of the whole city, began suddenly to speak." It appears, from his account of himself, that about three or four months before, he had heard the bells, and was extremely surprised by this new and unknown sensation. He observed, about the same time, water escape from his left ear, after which he heard perfectly with both ears. For three or four months he listened without attempting to speak to those about him, accustoming himself to repeat, in a very low voice, those words which he understood, strengthening himself in the pronunciation, and the ideas attached to the words. At last he broke silence, and spoke, though imperfectly. Immediately learned theologians were called to interrogate him, &c.

It is unfortunate for science that this young man was not observed by physicians; perhaps his history might then have been found more interesting.

A similar occurrence took place in Paris a few years since. A young man, who had been deaf and dumb from his birth, was cured of his deafness by Dr. Itard, by means of injections made into the drum through an opening formed in the membrana tympani. He at first heard the sounds of the bells in the neighbourhood, which produced a very vivid emotion; he was immediately seized with pain in the head and vertigo. The next day he was sensible of noises made in his apartment; in twenty-four hours

afterward he was able to distinguish the voice of persons who spoke to him. Then his delight became extreme; he could not satiate himself with hearing his friends speak; "his eyes," says Professor Percy, "seemed to seek the words upon their lips." His voice was not slow in developing itself; it formed at first but vague sounds, and in a short time he could stammer out a few words; but he pronounced them badly, and like a child. It was some time before he could pronounce compound words, or those which contained many consonants. An organ was suddenly played in his presence, when he immediately began to tremble, and turned pale, and was near fainting; afterward he experienced all those transports which we can imagine to be caused by a very vivid, but unknown pleasure: his flushed cheeks, sparkling eyes, rapid respiration, and quick pulse, announced a sort of delirium, an intoxication of pleasurable feelings. No doubt, many other surprising and interesting phenomena would have been observed in this young man, if disease had not removed him from the philosophical physicians who attended upon him.

But other cases of this kind have been observed. I have already commenced the history of Honoré Tresel, and will now finish it.

But all the interest felt by Honoré in the sensations procured by the sense of hearing did not prevent his making other important observations. His larynx formed sounds, and to the pleasure of hearing them he added that of producing them. In this respect his case presents some new and curious phenomena.

The instrument of the voice is composed of a great number of different parts, among which are muscles, bones, cartilages, and membranes. It would be surprising if all these different pieces, all these organs, could be made to act in concert, so as to form vocal sounds and appreciable articulation, without any preparatory exercise. But this would be impossible. The first sounds formed by Tresel were dull and grave; he pronounced, but with considerable difficulty, *a*, *o*, *u*; the two other vowels he attained at a later period. The first words that he pronounced were *papa*, *tabac*, *du feu*, &c.; but when he attempted to pronounce more complex words, he made a great many contortions with his lips, tongue, and other organs of pronunciation, of the uses of which he was entirely ignorant. He resembled, in this respect, a person learning to dance or swim, who makes many useless efforts and ungraceful movements; but, by persevering efforts, he at last succeeded in pronouncing some compound words, which at first transcended his powers of speech. Having accomplished this, he seemed to consider himself as having gained an equality with other children of his age. Hence, satisfied with himself and proud of his new situation, he conceived a great disdain for his old companions in misfortune, and appeared averse even to seeing them, thus manifesting one of the most deplorable instincts of our nature.

But, notwithstanding this ebullition of vanity, Tresel improved

but little in his pronunciation. A great number of syllables escaped, or were pronounced most imperfectly by him. Perhaps he would never have overcome this difficulty if his instructer had not ceased to address his efforts exclusively to the ear, but spoke also to his eyes.

He traced out for him a table with the different syllables, by which he was enabled to comprehend much better, seizing more distinctly upon the assemblage of vowels and consonants, and their reciprocal influence. A witness of this attempt, we were thus enabled to verify a most remarkable fact. It is, that the association of vision and the movements of the larynx were prompt and easy, while that of hearing and of the organ of the voice was always difficult, and executed slowly. As soon, for example, as Honoré saw the syllables written down, he could pronounce them, if kept near him; but if the table on which the letters were traced was taken away, it was in vain that certain syllables were pronounced to his ear; however distinctly they were articulated, it was impossible for him to pronounce them. Thus he seized with much greater facility the relations of the sounds with the written letters than with the action of his larynx.

By following this method, Tresel learned to read and write with great rapidity; but, like persons who study a foreign language, and who generally read and write it long before they are able to speak it, so, even to the present time, Honoré reads to himself, and writes much better than he speaks. His pronunciation is very defective: his sound of *r r* is especially peculiar and disagreeable. The different shades of accent appear to be unknown to him; but when we remember his original situation, it is gratifying to see him so far advanced in so short a period.

Honoré has presented another phenomenon, which has attracted the attention of the committee of the Academy of Sciences appointed to examine his case. When a word is addressed very distinctly to him, he immediately repeats it; if he is called, for example, by his proper name, he always repeats it. If his instructer wishes to address himself directly to his mind, he has recourse to gestures or to the expression of his countenance. The child himself can only express his ideas promptly and easily by signs, and it is only by means of these signs that it is possible to form a correct judgment of his intelligence and the promptitude of his conceptions.

In this respect Honoré presents an interesting phenomenon. Having acquired a new means of expressing his wants and ideas, it might have been supposed that he would have neglected the old method, so inferior to speech; but thus far it has been exactly the reverse: the natural language, that of signs, instead of being abandoned, and replaced gradually by speech, has rapidly gained, and acquired a perfection and piquancy much superior to what existed previous to his recovering his hearing.

However, in communicating with children of his own age, Honore begins to use simple words, particularly substantives, to make

known his wishes. Probably, in time, he will make a more general use of speech for expressing his thoughts and wishes, though perhaps he will always remain inferior to others in this respect. We have numerous examples of children who are, if we may be allowed so to express ourselves, mutes only because their ear is incapable of seizing upon words, combined with some difficulty about the larynx in speaking. Finding signs an easier mode of communication, they neglect to exercise the ear and the organs of speech, and thus remain classed among deaf mutes, when, in reality, they are neither deaf nor dumb.

I wrote an account of this case in 1825; since that time, Honoré has received every care and attention from M. Deleau. The Academy of Sciences has been at the expense of his education, as well as that of several other deaf children whose hearing has been restored. He has undoubtedly made great progress. It may be said, without exaggeration, that he both understands and speaks; but we confess that he is still decidedly inferior to others of his age who were not born deaf mutes. Should not time greatly improve his condition, we shall be compelled to conclude that a deaf mute from birth cannot, even by the most careful and prolonged education, be as well fitted for society as other men. Other analogous cases that have come under my observation have appeared to me to prove, that if hearing is restored to deaf mutes by their fifth year, they are much more apt to acquire speech, and use it, like other children, by their ear and voice, and to abandon the use of signs and gestures.

Of Sounds independent of the Voice.

Independently of the voice, man can produce at pleasure a great number of appreciable and unappreciable sounds, such as the noise which we make in the act of spitting or snuffing, that by which we call a horse, and the imitation of the sound of drawing a cork from a bottle; whistling through the lips or teeth, either in expiring or inspiring, and a multitude of other noises which result from the movement of different parts of the mouth, or from the manner in which the air penetrates into that cavity or passes out from it. It is not easy to account for the mechanism of these different sounds, particularly those which are appreciable, as that of whistling; we can only approximate this point.

CHAPTER XII.

OF ATTITUDES AND MOVEMENTS.

Muscular contraction not only produces the voice, but presides, also, over our movements and attitudes.

The explanation of the movements and attitudes of man consists in the application of the laws of mechanics to the organs which execute them. Our attitudes and movements being exceedingly various, in order to explain them it would be necessary to have recourse to all the laws of mechanics. No one has ever executed this labour in a satisfactory manner; they have generally limited themselves to those movements and attitudes which are the most frequent, and to the application of the most simple principles of mechanics.

The Mechanical Principles which are necessary to understand the Movements and Attitudes.

The line in which the weight of the body acts is called the *vertical line.* In every part of the body the vertical line passes through different points; but there is one point where all these lines cross each other: this is called the *centre of gravity.*

The *state of equilibrium* of a heavy body, placed upon a horizontal plane, is when a perpendicular, falling through the centre of gravity upon the horizontal plane, passes between those points on which the body rests.

The *equilibrium* of a heavy body upon a horizontal plane is firm in proportion as the centre of gravity of the body is near the plane, and the surface upon which it rests is extensive.

The *base of support* is the space included between those points on which a body is applied to the plane.

Of two hollow columns, formed of an equal quantity of the same materials, and of the same height, that which has the largest cavity will be the strongest.

Of two columns of the same diameter, but of different heights, the highest will be the weakest.

The greatest weight that a spring with small flexions can support, is proportional to the square of the number of flexions *plus* one; so that if the spring presents three curves, it will support a weight sixteen times heavier than if it had none.

Of Levers.

We define a lever to be an inflexible line which turns upon a fixed point. We distinguish in this instrument three parts, viz., the *fulcrum, the part to which the resistance,* and *that to which the power* is applied. According to the respective positions of the fulcrum, the power, and the resistance, the lever is of the *first, second,* and *third kind.* In the lever of the first kind, the fulcrum is between the resistance and the power, the resistance being at one extremity and the power at the other. The second kind of lever is when the resistance is between the power and the fulcrum, the fulcrum and the power occupying the two extremities. Lastly, in the lever of the third kind, the power is between the resistance and the fulcrum, the resistance and the fulcrum being at the two extremities.

We likewise divide a lever into the arm of the power and that

of the resistance. The first comprehends the portion of the lever which extends from the fulcrum to the power, the second is the portion included between the fulcrum and the resistance. When, in a lever of the first kind, the fulcrum occupies exactly the middle of the lever, we then say that the lever has equal arms; when the fulcrum is nearer either the power or the resistance, we then say it has unequal arms.

The length of the arms of the lever gives more or less advantage either to the power or to the resistance. If the arm of the power, for example, be longer than that of the arm of resistance, the increased advantage to the arm of power will be in proportion to its greater length; so that if the first of these arms be double or triple the second, it will be sufficient, if the power be one half or one third the resistance, to bring these two forces into a state of equilibrium.

In a lever of the second kind, the arm of the power is necessarily longer than that of the resistance, inasmuch as the fulcrum is at one extremity and the power at the other. This kind of lever is always advantageous to the power. The reverse is the case in a lever of the third kind, as then the power is between the fulcrum and the resistance.

A lever of the first kind is most favourable to an equilibrium, that of the second to overcome resistance, and a lever of the third kind conduces most to rapidity and extent of motion.

It is impossible to remark the direction in which the power is applied to a lever. The effect of the power is so much the more considerable, as the direction approaches nearer to a perpendicular to that of the lever. When this is the case, the whole force is employed to overcome the resistance; but when the direction is oblique, one part of the force tends to bring the lever into a proper direction, and this portion of the power is lost by the resistance of the fulcrum.

Moving Power.

That general property of matter, by which it remains in a state of motion or rest, when it is not acted upon by any foreign cause, is called its *vis inertia.*

The force which produces motion can only be measured by the quantity of motion produced. This is obtained by multiplying the mass by the velocity.

Velocity is acquired in two ways, viz., either by the continued action of a force, as in the gravity of bodies, or in consequence of a force which imparts instantaneously a given velocity.

From what has been said, it is easy to infer that every effort exerted upon a loose body will impart motion. The direction of the motion, its velocity, and the space it will pass over, must depend upon the mass, the intensity of the action exerted upon it, and the forces which act upon it during its motion. Thus a body thrown from the hand acquires instantaneously a velocity proportioned to the intensity of the effort and the mass of the project-

ed body. The continued action of gravity modifies incessantly both the velocity and the direction of the motion, which ceases when the body falls to the surface of the earth. The motion is also retarded by the resistance of the atmosphere, the effect of which increases with the velocity of the body, the extent of its surface which strikes against the air, and the specific gravity of the body.

An inorganic body cannot of itself change its state. If at rest, it must remain so until some force is applied to it. Being put in motion by the action of some force, it will continue a uniform motion in a right line until some new force modifies or destroys the effect of the first.

That is called *a uniform motion* in which the moving body passes over equal spaces in equal times. It is called *an accelerated motion* when the spaces are greater and greater; it *is retarded* when they become smaller and smaller, the time remaining equal. Hence it is evident that an *accelerated* or *retarded* motion will require at each instant the application of new forces.

In a *uniform motion*, the space passed over in a given time will be greater or less, according to the intensity of the force that has been applied. This relation of time to the space passed over by the moving body determines what is called *its velocity.*

If, in the same time that a body, A, has passed over a space of three feet, another body, B, passes over a space of five feet, we should say that the velocity of A is to that of B as 3 to 5.

It often happens that we express a velocity by an absolute number; but this number only represents the relation of that velocity with another which is not announced, but which is understood as standing for unity.

If a body in a unit of time (a second, for example) passes over a unit of space, as a foot, its velocity is chosen as a term of comparison, which is represented by unity. If a second body in the same time passes over five feet, its velocity, 5 times greater than the first, will be represented by 5. If a third body require three seconds to pass over 5 feet, which the second passed over in one, its velocity will be subtriple; consequently, the second being 5, it will be 5|3. We shall obtain, then, an expression of the velocity by dividing the number which represents the space by that which represents the time, which is generally more briefly expressed by saying that the velocity is equal to the space divided by the time.

In equal masses, the velocities will be proportional to the forces.

In equal velocity, the forces are proportional to the masses; for the effect of a force which puts a body in motion, is to impress the same velocity on all the molecules of that body, and, of consequence, the intensity of the force will be proportional to the number of molecules, or to the mass of the body. The measure of a force, then, is represented by the sum of the forces which animate all the molecules, or, as it is usually expressed, the effect of a force has for its measure the mass multiplied by its velocity.

To equal forces, the velocities will be reciprocally proportional to the masses. Thus, if to a body in motion there be attached another body at rest, so that the first cannot move without the second, the motion will spread itself uniformly in the two bodies, so that they will move with equal velocities. It will be necessary, then, that it should be distributed proportionally to the masses, and the resulting velocity will be to the velocity of the first body as the mass of the first body is to the mass of the two combined.

Friction is the resistance which one body is obliged to overcome in gliding over another.

The force which unites two polished surfaces, when brought in accurate contact with each other, is called *adhesion*. This force is measured by the effort required to separate them, acting perpendicularly to the surfaces. The more polished the surfaces in contact, the greater will be the adhesion, and the less the friction; when we wish, therefore, two bodies to glide upon each other, we polish the surfaces, or interpose some liquid between them.

THE BONES.

The bones determine the general form and dimensions of the body. In consequence of their physical properties, they fulfil a very important use in the different positions and motions; they form the different levers which the animal machine presents, and serve to transmit the weight of all the parts of our body to the earth. They are employed as levers of the first, second, and third kind. When they are *in equilibrio*, a lever of the first kind is almost always employed; if a considerable resistance is to be overcome, they represent a lever of the second kind; and in other movements, they are employed as levers of the third kind; which, as was before observed, though unfavourable to the action of the power, conduces very much to the rapidity and extent of the motions. The greater part of the projections and eminences of the bones serve to change the direction of the tendons, so that they may be inserted in a direction less distant from the perpendicular.

As means of transmitting weight, the bones represent hollow columns, which thus augment, very much, the general resistance of the skeleton and each bone.

Form of the Bones.

The bones are divided into *short*, *flat*, and *long*. The short bones are placed in those parts which are very solid, but have little mobility, as the feet, and the vertebral column. The flat bones chiefly compose the walls of the cavities; they concur, also, advantageously in the movements and attitudes, by the extent of surface which they present for the insertion of the muscles. The long bones are principally employed in locomotion, and are only found in the extremities. The form of their body, and that of their extremities, is particularly worthy of notice. The body is always the smallest part of the bones, and is generally rounded; but, on the contrary, they always grow larger at their extremi-

ties. This arrangement of the body of the bones assists in giving form to the limbs; and the increased volume of the articulated extremities, besides this use, gives solidity to the articulations, and diminishes the obliquity of the insertion of the tendons upon the bone.

The short bones are very spongy in their texture, by which they present a considerable surface without much weight. The same remark applies to the extremities of the long bones; but their bodies are very compact and heavy, which impart to them a great power of resistance, which was necessary, because these .parts have to sustain all the forces which act upon these bones.

The spongy tissue of the short, and the extremities of the long bones, are filled with a medullary fluid; the cavities of the long bones are filled with a substance called *marrow.*

Articulations of the Bones.

They are distinguished into those which permit, and those which do not permit motion. The first presents subdivisions, founded upon the form of the articulating surfaces. The second are also founded on the disposition of the articulating surfaces, and the kind of motions which these articulations permit.

In the movable articulations, the bones are never in immediate contact. There is always interposed between them an elastic substance, differently disposed, according to the articulation, and destined to support easily the strongest pressure, to weaken shocks, and facilitate motion. Sometimes this substance is homogeneous in its structure, adheres equally to the surfaces of both bones, and constitutes what has been called the *articulation of continuity;* it is then of a fibro-cartilaginous nature. Sometimes this substance is formed of a lamina on each articulating surface: this is what is called the *articulation of contiguity;* in this case the substance is cartilaginous.

It is said that the substance which covers the bone in this last kind of articulation is formed of fibres arranged at the side of each other, in a direction perpendicular to the surfaces which they cover. This opinion appears to me to merit farther investigation. The cartilages are of a homogeneous lamina.

The articulations thus arranged are most favourable to a gliding motion; the surfaces in contact are highly polished, and a particular liquid, the *synovia*, is continually poured out between them. For the same reasons, the adhesion is very strong, which adds to the solidity of the articulation in contributing to prevent displacements.

In certain movable articulations, we find between the articulated surfaces loose fibro-cartilaginous substances. They have been supposed to act like cushions, yielding to pressure, and afterward returning to their natural form, thus protecting those surfaces with which they are in contact. For this reason, it is said, they are found in those joints which sustain the most considerable pressure. We think this opinion is not sufficiently proved. In-

deed, they are not found in the hip, nor the ankle joints, which support, habitually, the greatest efforts. Do they not rather serve to favour extent of motion, and to prevent displacement?

About, and sometimes in the interior of joints, we find fibrous bodies which are called ligaments, which perform the double office of keeping the bones in their respective situations, and limiting the movements which they execute one upon another.

Attitudes of Man.

We will now examine man in the different positions which he can assume; and, first, in that posture which is the most common to him—that is, upon his feet.

We see, in the first place, that the head, united intimately with the *atlas*, forms with it a lever of the first kind, the fulcrum of which is the articulation of the lateral masses of the atlas, while the power and the resistance occupy each an extremity of the lever, represented, the one by the face, the other by the *occiput*. The fulcrum being nearer the occiput than the anterior part of the face, the head tends, by its own weight, to fall forward; but it is retained in *equilibrio* by the contraction of the muscles which are attached to its posterior part. It is the vertebral column, then, which supports the head, and transmits the weight to its inferior extremity. The superior extremities, the soft parts of the neck, the thorax, and the greater part of the abdominal viscera, press, more or less directly, upon the vertebral column.

In consequence of the great weight of these parts, it was necessary that the vertebral column should possess great solidity. Indeed, the bodies of the vertebra, the intervertebral fibro-cartilages, and the ligaments which bind these parts together, form a column of great strength. When we reflect upon the structure of the vertebral column, that it consists of portions of erect cylinders placed one above another, that it forms a pyramid, the base of which rests upon the sacrum, and that it presents three curvatures in opposite directions, which cause its power of resistance to be sixteen times greater than if it possessed none, we can then form some idea of the great resistance of which it is capable. We know that it is not only capable of supporting the organs which press upon it, but also burdens of great weight.

The weight of the organs which the vertebral column sustains causing it to incline forward, there are muscles placed along its posterior part which resist this tendency. Under these circumstances, each vertebra, and the parts of which it is composed, represent a lever of the first kind, of which the fulcrum is in the fibro-cartilage, which sustains the vertebra, the power in the muscles which draw it backward, and which are attached to the spinous and transverse processes, and the weight or resistance in those parts which draw it forward.

The vertebral column, as a whole, represents a lever of the third kind, of which the fulcrum is in the articulation of the fifth lumbar vertebra, with the *os sacrum*. In this case, the weight or

resistance is in those parts which tend to carry the column forward, and the power in the muscles which are placed on its posterior part. As the power acts principally at the inferior part of the lever, it is there that nature has placed the strongest muscles; it is there that the pyramid, represented by the vertebral column, has the greatest thickness, and that the apophyses of the vertebræ are more developed and more horizontal; it is also there that the sense of fatigue is first perceived, when we remain long in an erect position.

The muscular power will act efficiently in preserving the equilibrium necessary in standing, in proportion as the spinous processes are longer, and nearer the horizontal direction.

The weight of the vertebral column, and of the parts which press upon it, is transmitted directly to the pelvis, which, resting upon the thigh bones, represents a lever of the first kind, the fulcrum of which is in the ilio-femoral articulations, the power and resistance being placed posteriorly and anteriorly. The pelvis partly sustains the weight of the abdominal viscera; the sacrum supports the vertebral column, and, acting like a wedge, transmits equally to both of the thigh bones the weight, through the *ossa ilii.* The pelvis is in equilibrio upon the two heads of the thigh bones; this equilibrium results from a great number of combined efforts.

On one side, the abdominal viscera, pressing upon the pelvis, incline it forward, tending to depress the pubis; but the vertebral column, by its weight, acts in an opposite direction.

The weight of the vertebral column being much greater than that of the abdominal viscera, it would appear necessary to establish the equilibrium, that powerful muscles, passing from the thigh bones, should attach themselves to the pubis, and, by their contraction, counterbalance the excessive weight of the vertebral column. Such muscles, in fact, exist, but it is not the use of these muscles to preserve the equilibrium of the pelvis upon the thigh bones; for the pelvis, so far from having a tendency posteriorly, rather inclines anteriorly, because the muscles which resist the tendency of the vertebral column to incline forward, having the pelvis for their fixed point, have a considerable tendency to carry it upward. There are, again, those muscles which move the thigh bones on the posterior part of the pelvis, which prevent its being elevated, and which are the principal agents in preserving the equilibrium of the pelvis upon the thigh bones: nature has formed these muscles numerous and very powerful.

The articulations of the thigh bones with the *ossa ilii* are much nearer to the pubis than to the sacrum, from which it happens that the posterior muscles act upon the longest arm of the lever, which is favourable to their action.

In the erect posture of the body, the thigh bones transmit directly to the tibiæ the weight of the trunk. They fulfil easily this use, from the strength of their articulation with the *ossa ilii.*

Besides the uses which the necks of the thigh bones perform in

the various motions of the body, they are likewise useful in standing. As their head is directed inward and upward, they not only support the vertical pressure of the pelvis, but they have a tendency to prevent the separation of the *ossa ilii*, thus counteracting the opposite action of the sacrum.

The thigh bones transmit the weight of the body to the tibiæ; but, from the manner that the pelvis presses upon their inferior extremities, they have an inclination forward, while the contrary is the case at their superior extremities. In order to preserve their equilibrium upon the tibiæ, it is necessary, therefore, that there should be powerful muscles to oppose this tendency. The muscles by which this is effected are the rectus and *triceps femoris*, the action of which is favoured by the rotula placed behind their tendon. The posterior muscles of the leg, which are attached to the condyles of the femur, concur also in preserving the equilibrium.

The tibiæ transmit the weight of the body to the feet, without any assistance from the fibulæ. But, in order that the first of these bones may fulfil, conveniently, this office, it becomes necessary that the muscles should oppose the disposition which exists at their superior extremities to be carried forward. The gastrocnemii muscles fulfil this office in part, but all the muscles situated on the posterior part of the leg concur.

The feet sustain the whole weight of the body, for which their form and structure render them admirably suited. The sole of the foot is very extensive, by which the firmness of the erect position is secured. The skin and epidermis of this part are very thick. Beneath the skin is a lamina of fat, of considerable thickness, at those places where the foot presses upon the earth. This fat forms an elastic cushion, which diminishes the effect of the pressure produced by the weight of the body. The whole inferior surface of the foot does not touch the ground. The heel, the external edge of the foot, the part which corresponds to the anterior extremity of the metatarsal bones, and the extremities or balls of the toes, are the points which generally press upon the earth and transmit the weight of the body. We also find at each of these points fatty masses of considerable size, which are evidently intended to prevent inconvenience from too great pressure; that which is placed immediately beneath the head of the os calcis is very remarkable; it is attached by its superior face to the bone, but is distinct from the rest of the fatty substance which adheres to the heel. The other fatty masses, or cushions, are less voluminous, but are arranged in a manner completely analogous.

The tibia transmits the weight of the body to the astragalus, from which it is again imparted to the rest of the bones of the foot; the os calcis receives the greatest portion, and the remainder is divided between the other points of the foot which press upon the ground.

The following is the general mode by which this is effected. The weight that the astragalus sustains is transmitted, 1st, to the

os calcis; 2d, to the scaphoides. The os calcis, being placed immediately beneath the astragalus, receives the greater part of its pressure, which it transmits partly to the ground, and in part to the os cuboides. This last and the os scaphoides, through the medium of the cuneiform bones, press in their turn upon the metatarsal bones, which transmit to the ground nearly all the pressure they receive; the surplus is propagated to the toes. This mode of transmission supposes the foot to touch the ground through the whole extent of the sole.

As the pressure of the tibia is felt over all the internal part of the foot, it has a tendency to press it outward; the fibula is destined to counteract this when we stand in an erect position.

We have already seen that the muscles which prevent the head from falling forward arise from the neck; that those which fulfil the same office to the vertebral column arise from the pelvis; that those which preserve the pelvis in equilibrio are attached to the bones of the thighs and legs; that those which prevent the rotation of the thigh bones backward are inserted into the tibia; and, lastly, that those which retain the bones of the tibia in their vertical position have their fixed point in the feet. It is, then, in the feet that all the efforts required in standing are at last concentrated; it is necessary, therefore, that the feet should present a resistance proportionate to the efforts which they are destined to support. But the feet have not any other means of resistance than what arises from their weight; all the rest which they exhibit is communicated by the weight of the body which they support, so that the same cause which tends to produce a prostration of the body is also that which secures to it firmness in the erect position.

The space between the feet, as well as the surface which they cover, forms the base of support to the body. The state of equilibrium in the erect posture is a vertical line passing through the centre of gravity, and falling upon some point included within the base of support. The position will be firm in proportion to the extent of this base; in this respect, the size of the feet is far from being an indifferent circumstance.

We know, from observation, that this posture of the body is most secure when the two feet are placed parallel to each other, and separated by a space equal to the length of one of them. If we enlarge, laterally, the base of support, by separating the feet, the posture becomes more secure in that direction, but we lose our firmness anteriorly and posteriorly. It is the reverse when we place one foot before and the other behind.

The more the base of support is diminished, the less secure is the posture, and the greater the muscular power required to preserve it. This happens when we endeavour to elevate ourselves on our toes. In this case the feet only touch the ground in the space comprehended between the anterior extremity of the metatarsal bones and the extremities of the toes. This posture is very fatiguing, and cannot long be endured. Some persons, dan-

cers, for example, can elevate themselves upon the extremities of their toes, a thing which is extremely difficult. Besides, whatever may be the part of the foot which touches the ground, it is always comprised in the four parts which we have mentioned at the commencement of this article, and we cannot mistake, therefore, the uses of the fatty masses which are found there.

The position will also become very difficult, if not impossible, when the feet rest upon a very narrow plane—a tight rope, for example. We may generally remark, that whatever contracts the base of support, proportionally diminishes the firmness of the posture ; this any one may satisfy himself of by observing those individuals who have accidentally lost their toes by frost, or the anterior part of the foot by a partial amputation ; those who have one leg of wood, or persons walking upon stilts. In this last case, the position is rendered still more difficult by the distance of the centre of gravity from the base of support.

The position upon both feet may be varied infinitely. The trunk may be inclined before or behind, or laterally, and the inferior extremities be bent in different ways. Those who understand all that has been said of the erect posture will find no difficulty in explaining the attitudes here referred to.

Standing upon One Foot.

We sometimes stand on one foot; this attitude is necessarily fatiguing. It requires of the muscles which surround the hip joint a strong and continued action, by which the equilibrium of the pelvis upon one thigh is preserved. As the body, and, of consequence, the pelvis, is inclined to fall to that side on which the leg is not applied to the ground, there is required of the glutæus maximus, medius, minimus, tensor vaginæ femoris, gemini, pyramidalis, obturatores, and the quadratus femoris, such a contraction as will support the trunk. We may speak here of the use of the neck of the thigh bone, and of the projection of the great trochanter. It is evident that they render much less oblique the insertion of the muscles which have been before spoken of, and thus prevent so great a loss of power as would otherwise be the case.

It is scarcely necessary to add, that, in standing upon one foot, the base of support is only represented by the surface of the ground covered by the foot, and that it must, therefore, be necessarily less secure than when we stand upon both feet, whatever may be the posture. It will become still more difficult and tottering, if, instead of applying the whole surface of the foot to the ground, we rest upon one point of it. It is quite impossible to preserve this position longer than for a few moments.

Kneeling.

The base of support in this posture appears at first sight to be very large; and, as the centre of gravity is brought near the earth, one might suppose that it would be more secure even than

standing upon both feet. But the size of the base which sustains the weight of the body is far from being measured by the whole surface of both legs which touch the ground. The patella is nearly the only part which transmits the weight of the body to the ground. The skin also, which covers this part, is strongly pressed, and not being covered with a fatty cushion, as we see on the feet, it soon becomes injured if this position be long continued. For this reason, we are in the habit of placing cushions under the knees when we intend to kneel for any considerable length of time, by which we transmit the weight of the body to the ground through an intermediate substance which increases the base of support, and thus diminishes the effect of pressure. It is for a similar reason, that is, to increase the extent of the pressure caused by the weight of the body, that we bend the thighs backward, and throw the weight upon the legs and heels. The situation is much more solid and less fatiguing, because the base of support is much enlarged, and the centre of gravity nearer the ground.

Attitude of Sitting.

We may sit in different ways: on the ground, for example, with the legs extended, on a low seat, the feet touching the ground, or upon an elevated seat, in which the feet do not touch the ground, but are suspended, and the back supported or unsupported.

In all the positions where the back is not supported nor the feet touching, the weight of the body is transmitted to the ground by the pelvis, the size of which at its lower part is greater in man than in any other animal. The base of support by the trunk becomes distinct from that of the bones of the inferior extremities; it is represented by the extent which the parts occupy on the resisting plane which sustains them. The more voluminous and fat they are, the more solid will be the attitude of sitting.

When, in the posture of sitting, the back is not supported, it requires the permanent contraction of the posterior muscles of the trunk to prevent our falling forward. The position is on this account fatiguing, as we observe after sitting on a stool for some time, but which is not the case when the back is supported, as in sitting on a sofa. Then the muscles which support the head alone act, and are the only ones fatigued. High chairs are intended to prevent this inconvenience, as they sustain the back and head. Whatever be the manner of sitting, we can preserve this attitude for a long time. 1st. Because it requires the action of but few muscles. 2d. Because the base of support is large, and the centre of gravity near the earth. 3d. Because the nates, in consequence of the thickness of the skin and the quantity of fat, can support a strong and long-continued pressure without inconvenience.

Of the Recumbent Posture.

This is the only position of the body which does not require any muscular effort. This is the attitude of repose, and of those whose muscular powers are prostrated by disease. We can also endure this attitude for a long time. The only organ affected by this position is the skin, which corresponds to the base of support. The pressure of the weight of the body, though very much divided, soon causes a sense of uneasiness, and afterward of pain; and if the position remains long the same, as we find in some diseases, the skin becomes ulcerated, and sometimes gangrenous, particularly at those points which have the greatest pressure, as the posterior surface of the pelvis, the great trochanters, &c. It is to avoid this inconvenience that we endeavour to procure beds which are soft, and the elasticity of which permits a more equal division of the pressure upon all those points of the skin which correspond to the base of support.

OF MOTIONS.

There are two kinds of motions: the end of the first is to change the relative situation of the different parts of the body; that of the second, to change the situation of the whole body upon the surface of the earth. The one is called *partial*, and the other *locomotion.*

Of Partial Motions.

The greater number of partial motions make an inherent part of the different functions. Many have already been described, and the others will be in their turn. We shall only treat here of those which may be insulated in the history of the functions. We shall successively treat of those of the face, head, trunk, and superior and inferior extremities.

Partial Motions of the Face.

It is easy to perceive that these motions have two distinct ends. The first is to concur in the sensation of seeing, smelling, and tasting; also, the receiving of aliments, mastication, deglutition, voice, and speech. The second indicates the operations of the intellect and the passions.

Movements of the Eyelids.

The movements of the eyelids may be referred to *winking*, that is, the motion by which their edges approach, touch, or are brought in contact with more or less force. The muscles which execute these movements are the orbicularis and the elevator palpebræ. The nerves distributed to the orbicularis are the facial and a part of the branches of the fifth pair. The nerves of the elevator palpebræ is a branch of the third pair. Sir Charles Bell has shown by experiment, that the section of the facial nerve deprives the individual of the power of closing the eyelids. The eye remains

exposed to the air, and the animal does not wink, either spontaneously, or when a foreign body touches the conjunctiva. I have often repeated this experiment; it is exact.

I have found, in my researches on the fifth pair, that the division of the trunk of this nerve made in the cranium arrests also the movement of winking; but the muscles of the eyelids are not paralyzed; for if the light of the sun be suddenly thrown upon the eye, winking takes place. It appears, therefore, that the periodical occurrence of winking is connected with the sensibility of the conjunctiva, and that the destruction of this property leads to the cessation of this function. This movement, then, appears to be produced by a very complicated action of the nervous system. We see, indeed, that weariness, irritation of the conjunctiva, menaced violence, &c., cause us to wink; or if, by an effort, we keep the eye open for some time, it causes a disagreeable sensation of the conjunctiva.

We may also conclude, from my experiments, that the fifth pair exerts over the seventh an influence analogous to that which it exercises over the special nerves of the senses.

Motions of the Eye.

There is no organ that presents so complicated a motive apparatus as the eye, as respects the number of its muscles, and especially of the nerves that concur in it. We see in the orbit the four recti and the two oblique muscles of the eye; the third, fourth, and sixth nerves are almost exclusively destined to the muscles, and, consequently, to the motion of the globe of the eye.

Before inquiring into the mechanism of the motions of the eye, and what are their agents, it will be first proper to ascertain what are the movements of this organ.

It was remarked by Sir Charles Bell, that if we open the eyelids of a person while asleep, we find that the cornea and pupil are directed upward, and placed under the upper eyelid. The same thing occurs in a person who is very weak, and nearly unconscious; the eyes are not directed upon any particular object, but the globe is turned upward. The same phenomenon occurs at the approach of death, the tunica albuginea alone appearing in the opening of the lids. This has long been known among physicians as a fatal prognostic symptom.

The attachments of the recti muscles of the eye obviously indicate their uses, and what anatomy announces has been directly confirmed by the experiments of Sir C. Bell. This physiologist, desiring to satisfy himself whether the oblique muscles only imparted to the eye lateral motions, attached to the tendon of the superior oblique a small thread, at the extremity of which was hung a ring of glass, the weight of which drew the tendon from the orbit. On touching the eye with a feather, I have often seen, says he, the glass ring drawn up by the contraction of the muscle with such force that it escaped from my fingers. The same author cut across the tendon of the superior oblique in an ape.

The animal at first experienced some inconvenience, but afterward the eye recovered its natural expression, as if it had not been subjected to any operation. The section of the inferior oblique in another ape was followed by similar results. Having, in another case, cut the superior oblique muscles in an ape, he agitated his hand before the eyes of the animal. The right eye directed itself very much upward and inward, while the left presented the same movement, but in a less marked degree. But when the right eye had taken this position, it was depressed with difficulty. The general conclusion from these experiments is, that the division of the oblique muscles does not prevent the movements of the eye as regards vision, and that the principal use of these muscles is to preside over the movements by which the eye protects itself from the action of foreign bodies, and which are regarded by Sir C. Bell as involuntary.

But, notwithstanding the interest excited by these researches, still we cannot flatter ourselves that we perfectly comprehend the mechanism of the motions of the eye. I have observed various facts which indicate the necessity of new experiments.

If we wound the peduncle of the cerebellum, or make a complete section of it in the rabbit, the eyes assume a very remarkable fixed position. The eye of the wounded side is carried downward and forward; that of the opposite side is fixed upward and backward, consequently in a directly opposite position to that of the other eye. The same result arises from the section of the medullary part of the cerebellum, or the pons varolii, or the lateral part of the medulla oblongata.

The first time that I observed this phenomenon, I believed that it depended on some lesion that I had caused unintentionally of the fourth pair of nerves, the origin of which is so near to the cerebellum. But I soon satisfied myself that this was not the case, my dissections after death leaving no doubt on this point. But, to show this more clearly, I divided, in many living animals, the fourth pair, on one side and on both. It was not without surprise that I found that this operation caused no modification in the position of the eyes. I am still engaged in experimenting upon the other nerves of the orbit; but this result is sufficient to show that the brain influences the position and movements of the eyes in a manner as yet quite inexplicable.

Independently of those motions of the face which concur in vision, smelling, tasting, voice, and speech, of which we have already spoken, and of those which serve to receive the food for mastication and deglutition, &c., of which we shall speak in their proper place, the muscles of the face cause in this part motions which serve to express certain intellectual acts, different dispositions of the mind, and instinctive desires and passions. Pleasure and pain, joy and sadness, desire and fear, anger, hatred, love, &c., have each an expression in the face which characterizes them. The painful and gloomy affections, and violent desires, are generally accompanied with a contraction of the coun-

tenance. The eyebrows are contracted into a frown, and the angles of the mouth drawn backward and downward; on the contrary, during the existence of the mild and amiable affections, gayety, agreeable sensations, and satisfied desires, the form of the face is expanded, the eyebrows elevated, the eyelids separated, and the angles of the mouth drawn upward and backward, which produces smiling. It is found that persons in whom the different expressions are the most strongly marked, or, as it is commonly expressed, whose *physiognomy* is the most remarkable, are usually distinguished for the vivacity of their character.

It is generally the reverse with persons whose countenances are without expression. When any particular disposition of the mind or passion is long indulged in, the muscles which are habitually contracted to express it acquire a manifest superiority in volume over the other muscles of the face. The physiognomy, therefore, preserves the expression of the passion, even when it is not perceived, or a long time after it has ceased, and is generally a correct index of the character and habitual passions of the individual.

According to the experiments of Sir Charles Bell, confirmed by many well-established pathological facts, it is proved that the facial nerve presides over the different movements of expression. If this nerve be cut or altered by disease, all expression on that side of the face will be lost, even although the sensibility remain perfect. We have already stated that the last phenomenon depends upon the branches of the fifth pair.

The colour of the skin of the face is also a powerful means of expressing the intelligence and passions. We shall treat of this subject under the article *capillary circulation.*

Motions of the Head upon the Vertebral Column.

The head may be inclined anteriorly, posteriorly, or laterally; it may also execute a rotary motion, either to the right or to the left. The motions by which the head is inclined forward or backward, or sideways, if they are not extensive, take place in the articulation of the head with the first cervical vertebra; but if the extent of motion is considerable, all the vertebræ of the neck take a part in it. The rotary motions are essentially executed in the articulation of the atlas with the dentatus, which is evidently intended for this purpose. These different movements, which are frequently combined together, are performed by the successive or simultaneous contraction of the muscles, which extend from the chest and neck towards the head.

It is easy to see that the movements of the head favour vision, hearing, and smelling; they are also useful in the production of the different tones of the voice, by permitting the elongation or shortening of the trachea, the vocal tube, &c. These movements serve also as a means of expressing some of the operations of the mind, as approbation, consent, refusal, &c., which are indicated by certain motions of the head upon the neck. Some passions

also induce certain movements or particular attitudes of the head.

Movements of the Trunk.

We shall only speak in this article of particular movements of the vertebral column; those which are peculiar to the thorax, the abdomen, and the pelvis, will be exposed hereafter.

Flexion, extension, lateral inclination, circumduction, and rotation are the motions executed by the vertebral column as a whole; these are also executed by each region, and even by each particular vertebra. These different motions take place in the intervertebral fibro-cartilages; they are, likewise, more easy and more extensive, as these fibro-cartilages are thicker and larger. For this reason, the motions of the cervical and lumbar portions of the vertebral column are evidently more free and more considerable than those of the dorsal portion. It is well known that the cervical fibro-cartilages, and especially the lumbar, are proportionally thicker than the dorsal.

In the motions of flexion, either anteriorly, posteriorly, or laterally, the fibro-cartilages are pressed down in the direction towards which the flexion is made; of course, then, that part which is thickest will be pressed down the most; this is one of the reasons why flexion anteriorly is much more extensive in the vertebral column than in any other direction.

In rotation, all the intervertebral bodies must undergo a lengthening of the plates which compose them. The centre of the bodies of which we are now speaking is soft, and almost fluid; the circumference only offers a considerable resistance to those motions in which the vertebræ are made to approach each other, but this circumference yields sufficiently to form a sort of pad between the two bones. The disposition of the articulating *facettes* of the vertebræ is one of the circumstances which have most influence upon the extent and mode of the reciprocal motions of the vertebræ.

When we consider the motions of the vertebral column as a whole, it represents a lever of the third kind, the fulcrum of which is in the articulation of the fifth lumbar vertebra with the sacrum; the power is in the muscles which are attached to the vertebræ, and the resistance in the weight of the head, the soft parts of the neck, chest, and part of the abdomen. Each vertebra, on the other hand, taken separately, represents a lever of the first kind, the fulcrum of which is in the middle, upon the vertebra placed directly underneath; the power is posterior, and the resistance anterior, or the one to the right hand, the other to the left, towards the extremities of the transverse processes.

The motions of the vertebral column are frequently accompanied with those of the pelvis upon the thigh bones; they then appear to have an extent of motion far greater than they actually possess.

The motions of the vertebral column are often useful in assist-

ing those of the superior and inferior extremities, and of rendering less fatiguing the different attitudes which the body assumes as a whole.

Motions of the Superior Extremities.

The superior extremities being the principal agents by which we effect, directly or indirectly, those changes in surrounding bodies that we desire, therefore require extreme mobility to be united with a sufficient degree of solidity. We find in these members many long bones, several of which are of considerable length, and slender; the short bones are small, and both of them are light; the articulating surfaces are of small dimensions; the muscles are numerous, and their fibres very long. The bones almost always represent levers of the third kind, which are favourable, as has been before remarked, to extent and rapidity of motion. When we consider the motions of the superior extremities as a whole, in relation to the trunk, or those of the different parts as they respect each other, we readily perceive that they unite, in a very eminent degree, great extent, rapidity, and variety of motion. The solidity of these members is not less worthy of remark. In numerous situations, they have to support considerable efforts, as when we support ourselves upon a cane, or when we fall forward, and the hands receive the whole shock of the fall, &c.

It is impossible for us to enter into all the details of this wonderful piece of mechanism.. We refer the reader, on this point, to " L'Anatomie Descriptive" of Bichat, whose genius exerted itself with great success in explaining the mechanism of animals.

The superior extremities are essentially useful in exercising the sense of touch, of which the hand is the principal organ. They assist us also in exercising the other senses; they aid us in bringing objects near, or in carrying them to a distance, or in placing them under circumstances favourable to the action of the senses. Their motions concur powerfully in expressing certain intellectual and instinctive acts. The gestures form a true language, which is susceptible of acquiring great perfection, and which may become of the greatest utility, as happens in the deaf and dumb. In these cases, the gestures not only paint the sentiments, wants, and passions, but they also express the slightest shades in the faculty of thought.

The superior extremities are often useful in the different attitudes of the body. In some cases, they transmit to the earth a part of its weight, enlarging, of course, the base of support. This is done when we rest upon a cane, or when, being upon our knees, we place the hands upon the ground; or when, in sitting upon a horizontal plane, we lean upon one or both of our elbows, &c. They also increase the security of the posture of standing erect, when we carry them in a direction opposite to that in which the body is inclined to fall by its own weight. We see every hour that they are useful in different modes of progression.

Movements of the Inferior Extremities.

Although there is a manifest analogy between the structure of the superior and inferior extremities, it is, nevertheless, evident in the last, that nature has attended much more to their solidity and extent of motion than to their rapidity and variety. This was necessary, for it is rare that these members move without supporting the weight of the body ; they are the principal agents in locomotion.

When we impress certain modifications upon foreign bodies by the inferior extremities, they move independently of the trunk. Thus, when we change the form of a body, by pressing upon it with the foot, or when we displace it with a blow of this part, or when we exercise the sense of touch with the foot, to judge, for example, of the resistance of the ground on which we intend to walk, &c., it is plain that these different motions do not drag the trunk after them.

We shall not describe here particularly the different general or partial motions which the members can effect; we shall only speak briefly of the different modes of locomotion, that is, of those motions by which the body is transported from one place to another, which are, walking, running, leaping, and swimming.

Locomotion.—Of Walking.

The action of walking is not always executed in the same manner. We may walk forward, or backward, or sideways, or in any intermediate direction; we may walk upon an ascending or descending plane, and upon a solid or movable body ; walking differs according to the extent and quickness of the steps, &c. Whatever may be the mode of walking, it is necessarily composed of a succession of steps; so that the description of walking only relates to the manner in which a series of steps are taken. It is only necessary, therefore, to inquire into the manner in which the art of stepping, with its various modifications, is performed.

Suppose a man, then, standing in an erect position, with both feet at the side of each other, and about to walk on a horizontal plane, at a common pace both in extent and quickness. It will be necessary to bend one of the thighs upon the pelvis, in order to raise the foot from the ground, by a general shortening of the limb. The flexion of the thigh throws forward the whole limb: the foot is then applied to the ground; the heel touches first, and afterward the whole inferior surface of the foot. When this motion is effected, the pelvis rolls forward upon the head of the thigh bone, which is immovable. This rotation of the pelvis upon the head of the femur has for its object, 1st, to carry forward the whole of the member which was raised from the ground; 2d, also to carry forward the side of the body corresponding to the limb which is moved, while the side corresponding to the unmoved limb remains behind. These two effects are hardly perceptible when the steps

are very short; they are remarkable in a common walk, but are much more so when we take long steps. Thus far there has been no progression, the base of support is only modified; in order that the step may be completed, it is necessary that the member remaining behind should be moved up, either in the same line or beyond that which was first moved. For this purpose, the foot which is behind is detached from the ground, successively from the heel towards the toe, by a rotary motion, of which the centre is in the articulation of the bones of the metatarsus with the phalanges of the toes, so that at the end of this motion the foot no longer touches the ground at its posterior extremity. From this movement of the foot there is an elongation of the limb, the effect of which is to carry the corresponding side of the trunk forward, and to determine the rotation of the pelvis upon the head of the femur of the limb first moved. This motion being executed, the limb becomes flexed, the keee is thrown forward, and the foot detached from the ground; afterward the whole limb describes the same motions which had been before executed by the limb of the opposite side.

By this succession of motions of the inferior extremities, and of the trunk, walking is executed, during which we see that the heads of the thigh bones are by turns fixed points, on which the pelvis turns as on a pivot, describing arcs of circles proportioned to the extent of the steps.

In order that we may walk in a right line, it is necessary that the arcs of circles described by the pelvis, and the extension of the lower limbs, when they are carried forward, should be equal; without this we shall deviate from a right line, and the body will be directed towards the side opposite to the limb the motions of which are the most extensive. As it is difficult to make the two limbs execute successively exactly the same extent of motion, there is always a tendency to deviate from a straight line, which would constantly occur if this deviation was not corrected by the sight. Any person may easily convince himself of this by walking some distance with the eyes closed.

Having exposed the mechanism of walking forward, it will be no very difficult task to explain walking backward or sideways.

In walking backward, one of the thighs is bent upon the pelvis, at the same time the leg is bent upon the thigh, the extension of the thigh upon the pelvis succeeds, and the whole of the limb is carried backward. After the leg is extended upon the thigh, the anterior part of the foot touches the ground, and immediately afterward the whole of its inferior surface. At the moment that the foot directed backward is applied to the ground, that which remains before is raised upon its toe, and the corresponding member elongated; the pelvis is thrown backward, making a rotation upon the head of the thigh bone, which is directed backward. The limb which is before is entirely raised from the ground, and carried backward, in order to furnish a fixed point for a new rotation of the pelvis, which will be executed in its turn by the opposite member.

When we wish to execute a lateral motion, we bend slightly one of the thighs upon the pelvis, in order to raise the foot from the ground; then throw the extremity into a state of abduction, and apply the foot to the ground, and immediately afterward we draw up the other limb towards the one which has been displaced, and so on.

When we walk upon an ascending plane, we know that it produces great fatigue. In this mode of progression, the flexion of the limb carried first forward must be considerable, and the extremity remaining behind must not only execute the motion of rotation upon the pelvis, but it is necessary that it should raise the whole weight of the body, in order to transport it to the member which is before. The anterior muscles of the thigh carried forward are the principal agents in the transportation of heavy bodies; these muscles are also very much fatigued in the action of passing up a ladder, or any other ascending plane.

For opposite reasons, walking upon a descending plane is more fatiguing than upon a horizontal plane. Here the posterior muscles of the trunk must act with force, to prevent the body from falling forward.

All the modes of progression which we execute rapidly require easy movements in all the articulations of the inferior extremities, and an equal action of every part of the limbs; the least imperfection in the articulating surfaces, or their mode of gliding upon each other, the least difference in the length or form of the extremities, or the contractile force of the muscles, unavoidably cause sensible alterations in the progression, and render it more or less difficult.

Of Leaping.

If we examine with attention the action that we are now about to investigate, we shall perceive that, during this motion, the body becomes a projectile, and that it is governed by all the laws peculiar to them.

A leap may take place either perpendicularly, anteriorly, posteriorly, or laterally, &c. We must in all these cases consider all the circumstances which accompany it. Every kind of leaping must necessarily be preceded by a flexion of one or more of the articulations of the trunk and inferior extremities; the sudden extension of these flexed articulations is the particular cause of the leap.

Suppose the leap to be made vertically, which is the most common; the head is bent upon the neck, the vertebral column is curved anteriorly, the pelvis is bent upon the thigh, the thigh upon the leg, and this again upon the foot, and the heel either touches the ground lightly, or not at all. This state of general flexion is suddenly succeeded by a universal extension of the flexed articulations; the different parts of the body are rapidly elevated with a force which surpasses its weight, in a variable degree. Thus the head and chest are directed superiorly by the extension and re-

traction of the vertebral column; the trunk, as a whole, is affected in the same way by the extension of the pelvis upon the thigh bones; the thighs being raised suddenly, act upon the pelvis, and the legs, in their turn, act upon the thighs. From all these united efforts, there results a projectile power, by which the body is raised from the ground, and the elevation will be in the proportion of the superiority of the power to the weight; after which it falls to the ground, presenting the same phenomena as all other bodies which are operated upon by the attraction of gravitation.

In the general retraction by which the leap is produced, the muscular contraction does not take place equally in every part. It is plain that it must be the greatest where the weight to be raised is the most considerable. This is the reason why the muscles which extend the leg upon the foot are those which act with the most energy, inasmuch as they raise the whole weight of the body, and give to it an impulse which surpasses its resistance. These muscles are admirably arranged for this purpose. They are extremely powerful, and are inserted perpendicularly to the lever which they are to move, the os-calcis, and act by the arm of a lever which has considerable length.

It is proper to remark, that the vertical leap does not result from any direct impulse, but it is a mean between opposite impulses, which the trunk and inferior extremities impart at the instant of the leap. Indeed, the retraction of the head, the vertebral column, and the pelvis, has rather a tendency to throw the trunk posteriorly than superiorly; the rotation of the thigh bones upon the tibiæ, on the contrary, carries the trunk rather anteriorly than superiorly; the motion of the leg, again, has a tendency to throw the trunk superiorly and posteriorly. When the result of the exertion is a vertical leap, the forces which carry the body forward and backward destroy each other, and those which throw the body upward alone take effect.

When the leap takes place anteriorly, the rotation of the thigh predominates over the impulses posteriorly; when the leap is made backward, it is the motion of extension in the vertebral column, and of the tibia upon the foot, which produce the effect.

The length of the bones of the inferior extremities is advantageous for extending the leap. We pass over the greatest possible distance in leaping forward: this is attributable to the length of the thigh bone. Sometimes we precede the leap by running a short distance forward; the impulse which the body thus acquires is added to that which it receives at the moment of the leap, by which its extent is increased.

The arms are not entirely useless in leaping. They are brought towards the body at the moment when the flexion of the different articulations is made, preparatory to the act of leaping. They are thrown out, on the contrary, at the moment when the body leaves the ground. The resistance which they present to the muscles which elevate them enables the muscles to exert some

force in throwing the trunk upward, and thus to concur in the act of leaping.

The arms fulfil this purpose more effectually when they present a firm resistance to the contraction of the muscles which elevate them. The ancients having made this remark, carried in each hand weights, called *halteres*, when they wished to exert themselves in leaping; by properly adjusting the arms, we can favour a horizontal leap, thus giving to the superior part of the body an impulse backward or forward.

We are capable of leaping with one foot, or, as we commonly express it, *hopping*. But this mode of leaping must be necessarily less extensive than when the effort is made simultaneously by both limbs. Sometimes we leap with both feet in contact, and parallel to each other ; sometimes one foot is carried forward during the projection of the body ; in this case one foot receives the weight of the body at the moment it touches the ground.

No impulse will be communicated to the body by the plane which sustains it at the moment of leaping, unless it be elastic, and combines its reaction with the effort of the muscles. In general, the ground serves no other purpose than that of resisting the pressure exerted by the feet. Every person knows that it is almost impossible to leap when the ground is soft, and yields to the pressure of the feet.

Of Running.

Running is a combination of walking and leaping ; or, rather, it consists of a succession of leaps, executed alternately by each limb, while the other is carried forward or backward, to be applied to the ground, and to produce the leap as soon as the first has had time to be carried backward or forward, accordingly as we run in one or the other direction. We may run with more or less rapidity, but there is always a moment when the body is suspended, in consequence of the impulse communicated to it by the limb which remains behind when we run forward. This constitutes the difference between running and walking fast, in which the foot carried forward touches the ground before that which is behind leaves it.

For the same reasons which we have given under the article *walking*, running is least fatiguing upon a horizontal plane. When it is executed upon an ascending or descending plane, it is always more or less laborious, and cannot be continued long.

We shall not even briefly describe the numerous modifications in the progressive motions of man, such as climbing, walking with crutches, stilts, and artificial limbs ; or of the different motions either in common dancing, or upon a tight or slack rope ; or those which are executed by tumblers, fencers, and riders, &c. Considerations of this kind are important, but they can only compose a part of a complete treatise upon animal mechanics ; a work which still remains to be executed, notwithstanding what has

been done by Borelli and Barthez on this subject. We shall only say a few words of swimming.

Of Swimming.

The body of man is specifically heavier than water ; of consequence, when left in the midst of a considerable mass of this fluid, he will sink to the bottom ; this will take place with so much the more facility, as the surface which strikes the water is of small extent. If, for example, the body is placed vertically, the feet below and the head above, it will sink much more rapidly than if the body was placed horizontally on the surface of the fluid. Some individuals, however, possess the faculty of rendering themselves specifically lighter than the water, and, of consequence, of resting without any effort upon its surface. This is effected by filling the chest with a large quantity of air, the specific gravity of which, being much less than the water, counterbalances the tendency which there is in the body to fall to the bottom.

It is not, however, by this practice that swimmers are enabled to move along the surface of the water, but by the motions which they execute with their limbs. The object of the motions executed by the swimmer is to sustain the body on the surface of the water, or to direct its progression. Whatever may be the intention of the swimmer, he must act upon the water in such a manner that it shall present sufficient resistance to support his body. According to this view, he acts upon the water by pressing suddenly upon it before it has time to escape, acting rapidly upon a great number of points by the action of his hands and feet, the resistance being in proportion to the mass of water displaced. The motions of the inferior extremities in the common manner of swimming are very analogous to those which they execute in leaping. There are various modes of swimming, but in all it is necessary to strike or press the water rapidly before it can be displaced.

It is impossible for a man to fly ; his specific gravity, when compared with the atmosphere and the force exerted by the contraction of his muscles, is infinitely too weak. All the attempts heretofore made with this intention, by machines formed in imitation of the wings of birds, have been equally unsuccessful.

Influence of the Brain on the Motions.

Recent investigations have imparted some very curious information respecting the influence of the brain over the movements. Science has become enriched with entirely new facts, which enable us to view the movements in a very different manner from what they were formerly regarded. I regret that the nature of this work will not allow me to present all the details of the experiments; but I shall endeavour not to omit anything that is important. I would refer to the Journal of Physiology, where all these researches will be found.

Influence of the Hemispheres on the Movements.

The cerebral hemispheres may be cut deeply at different points of their superior surface without causing any alteration in the movements. They may be entirely removed, provided the corpora striata are not touched, without much appreciable effect, and this not apparently referrible to the suffering consequent upon such an experiment. These results are not the same in all classes of the vertebrated animals. Those which I have described have been observed in the mammiferous animals, particularly dogs, cats, rabbits, Guinea-pigs, hedge-hogs, and squirrels. In birds, the abstraction or destruction of the hemispheres, the optic tubercles remaining intact, induces a state of stupor and immobility, which was first described by Rolando. But I have seen, in several cases, birds run, leap, and swim after their hemispheres had been removed; the vision appears to be destroyed. With respect to the reptiles and fishes on which I have operated, the removal of the hemispheres seems to produce but little effect on their movements. Carp swim with agility; frogs leap and swim as if nothing had been done; even the vision does not appear to be entirely abolished.

The spontaneous motions do not appear to depend exclusively upon the hemispheres, as a French physiologist supposed. This fact, true as it respects certain birds, as pigeons, full-grown rooks, &c., does not hold good of all other birds. But it is altogether inapplicable to the mammiferi, reptiles, and fishes—I mean those that I have experimented on. A longitudinal section of the corpus callosum and its removal do not produce any apparent effect upon their movements.

Influence of the Corpora Striata upon the Movements.

While the hemispheres alone are injured, the results are as has been mentioned. But if the operation made to extract these organs extends behind the corpora striata, and the latter are removed from the cranium, the animal immediately darts forward, and runs rapidly. If he stops, he preserves the attitude of flight. This phenomenon is particularly remarkable in young rabbits; one would say that the animal was urged forward by an internal irresistible power. In his rapid flight he sometimes passes over obstacles in his way, but does not see them. It is very important to remark that these effects only take place when the white and radiated part of the corpora striata is detached. If we only remove the gray matter which forms the segment of the curved cone, no modification of the movements is developed. But that which is not determined by the removal of the gray matter shows itself as soon as the white is affected; the animal becomes agitated, and endeavours to escape. If only one of the corpora striata be removed, the animal retains its power over the motions. It directs them in different ways, and stops when it pleases; but immediately after the section of the remaining cor-

pus striatum, the animal rushes forward as by an irresistible power. There is a disease of horses that has great analogy with this singular phenomenon. It is called among the French *immobilité*. An animal attacked by it walks forward easily, trots, and even gallops rapidly, but is incapable of going backward. and often seems incapable of stopping his progressive movements. I have opened a number of these horses with watery effusion into the lateral ventricles, which must have compressed the corpora striata, and had even altered their surface.

Finally, sometimes even man is irresistibly urged to an onward movement. M. Piedaquel has related, in the third volume of my Journal, a case of this kind. After the description of various cerebral symptoms observed in this patient, M. Piedaquel adds, "At the moment when the stupor was at its height, he suddenly rose, and walked in an agitated manner, making several turns round the chamber, and not stopping until he was exhausted. One day the chamber did not appear to him sufficient; he went out, and walked as long as his strength would permit. He was out about two hours, and was brought back in a litter. He had fallen down in the street. The next day he went away again; his wife endeavoured to stop him. He was annoyed, and attempted to strike her; she then suffered him to go, but followed him. All that she could say would not induce him to tell her where he was going, or to stop and rest himself. After walking for an hour and a half without object, as if urged on by a force that he could not resist, and becoming very much fatigued, he stopped."

On opening his body after death, there were found a number of tubercles in the anterior part of the hemispheres.

It is, then, extremely probable that there exists, both in mammiferous animals and man, a force or impulsion, which tends to urge him forward. In a healthy state, it is directed by the will, and seems to be counterbalanced by another force, which acts in an opposite direction, of which we shall speak. This phenomenon is not observable in other classes of the vertebrated animals.

Influence of the Cerebellum on the General Movements.

The influence of the cerebellum on the movements was studied experimentally several years since, and by many persons, but particularly by M. Rolando, of Turin, who regarded this organ as the source of all muscular contractions. This able writer removed the cerebellum in the mammiferi and birds, and remarked that the movements diminished in proportion to the quantity of cerebral matter removed. He ascertained that all motion ceased when the whole of this organ was removed. Assuming this result as general, M. Rolando endeavoured to show how the cerebellum could produce these muscular contractions. The great number of alternate gray and white laminæ presented by the brain he regarded as a voltaic pile, which developed electricity, and excited the movements.

Although the fact announced by M. Rolando has often occurred under my observation, yet I cannot admit his explanation. I have seen, and often shown to others in my course of lectures, animals deprived of their cerebellum, which, nevertheless, continued to execute the movements regularly. I have seen, for example, hedgehogs and Guinea-pigs, deprived both of the cerebrum and cerebellum, rub their nose with their paws when I placed a bottle of vinegar under it.

Now here a single positive fact outweighs in value all negative facts. There could be no doubt of the exactitude of the experiment, and of the removal of the whole of the cerebellum. The experiment was made in a manner to leave no uncertainty on this point.

These experiments also respond to an idea suggested by a physiologist already cited, M. Flourens, who has given to the cerebellum the power of regulating or balancing the movements. A fact that has been observed by all who have experimented upon the cerebellum is, that lesions of this organ impel animals to go backward, and even compel them to execute this movement, evidently against their will. I have often seen animals with wounds of the cerebellum attempt to advance, but still, as it were, forced backward. I kept a duck for eight days after having removed the greater part of the cerebellum; during this time it made no other progressive movement; it was the same when I placed it on the water.

I have seen lesions of the medulla oblongata produce this disposition to go backward. Thus this disposition is not exclusively confined to injuries of the cerebellum. I have found, when a pin was forced into this part in a pigeon, that this disposition to go backward continued for a month, and that it even flew backward: a singular movement, entirely contrary to the usual habits of the bird. The inference obviously deducible from these experiments is, that there exists in the cerebellum and medulla oblongata an impulsive force, which urges animals forward. It is probable that a similar force exists in man. Dr. Laurent, of Versailles, some years since showed me, and afterward exhibited before the Royal Academy of Medicine, a young girl who, in attacks of a nervous disease, was compelled to go rapidly backward, without the power of avoiding obstructions in her way.

This is in direct opposition to that of the corpora striata, of which we have spoken. This impulsive force backward is only found in the mammiferi and birds. I have often taken away the cerebellum in fishes, and what is considered this part in reptiles, but have found no such phenomena in them. Their movements are but little affected. These results render probable the existence of two opposite internal forces, which are in equilibrio while the animal is in health, but which will be shown as soon as lesion of the corpora striata or cerebellum shall render either the one or the other predominant. These two forces do not appear to be the only ones derived from the cerebro-spinal system. There

probably exist others, which preside over the lateral and rotatory movements.

Influence of the Peduncles of the Cerebellum upon the Movements.

If one of the peduncles of the cerebellum be divided in a living animal, it immediately begins to roll laterally upon itself, as if it was urged by some strong power. The rotation is made from that side where the peduncle was divided, and sometimes with such rapidity that the animal will make fifty revolutions in a minute. The same kind of effect is produced by vertical sections of the cerebellum from before backward through the medullary arch formed above the fourth ventricle ; with this remarkable circumstance, that the motion is more rapid as the section approaches nearer to the origin of the peduncles, that is, their communication with the pons varolii. These effects are not limited to a few hours ; I have seen them continue thus for eight days, the animals not appearing to suffer. They remained in a state of repose when they met with any mechanical obstacle to their rotation ; their feet often in the air, and eating in this attitude. I made another curious experiment—cutting the cerebellum into two equal halves. The animal then appeared to be urged alternately to the right and left, without preserving any fixed situation. If it rolled a turn or two on one side, soon it changed, and turned as many times in the opposite direction.

Influence of the Pons Varolii on the Motions.

It is known that the peduncles of the cerebellum are continuous with the pons varolii, and that there exists thus a complete circle about the medulla oblongata. The superior half of the circle is formed by the arch which the cerebellum represents, and the inferior half is represented by the pons, and more exactly by that part now called the commissure of the cerebellum. I shall now describe what takes place as a consequence of a vertical section of the superior semicircle : I have found, from experiment, that it is the same for the inferior circle.

All vertical sections of the pons varolii from before backward produce the movement of rotation in a manner similar to what I have described. Sections made to the left of the median line determine the rotation to the left, and *vice versa.* I have never succeeded in making a section exactly on the median line, so that I am ignorant if it would be the same with the pons as with the cerebellum.

However this may be, we may conclude from these facts that there exist two forces, which are in equilibrio in passing through the circle formed by the pons varolii and the cerebellum. To place this beyond doubt, we may make the following experiment : Divide one of the peduncles, and immediately it will roll, as has been already described. Then cut the one of the opposite side, and rotary motion will immediately cease, and the animal will have lost the power of standing and walking.

I do not pretend to express here, with the necessary exactitude, the nature of the phenomena that I have described. But, as our minds require certain images, I will say that there exists in the brain four spontaneous impulsions, or forces, which may be placed about the extremities of two lines, which cross each other at right angles. The first urges forward ; the second, backward ; the third, from the right to the left, causing the body to roll ; the fourth, from the left to the right, causing it to execute a similar movement of rotation.

These four general movements are not the only ones produced by determinate lesions of the nervous system. A movement in a circle, from right to left, follows a section of the medulla oblongata, made so as to affect that portion of the medulla which approaches externally the anterior pyramids. I made this experiment on a rabbit three or four months old. I laid bare the fourth ventricle ; then raising the cerebellum, I made a perpendicular section to the surface of the ventricle, and three or four millimetres outwardly from the median line. If I cut to the right, the animal turned to the right ; and to the left, when I cut to that side. Thus, there are two new impulsions, which excite different movements from the four principal ones that I have above described.

All these experimental results on the functions of the cerebellum and pons varolii show the necessity of new researches. This becomes still more urgent from a most extraordinary pathological fact recently observed.

A young girl lived to the age of eleven years, with sensations and motions weak, it is true, but sufficient for all her wants, and even for progression. During the last month of her life, her inferior extremities were paralyzed as respects motion, but not sensibility. On making a minute examination, which I did personally, with all the care of which I am capable, there was found complete absence of the cerebellum, and of its commissure, that is, the pons varolii.—(See the very curious details of this unique case in the *Journal de Physiologie*, t. xi.)

Influence of the Pyramidalia on the Movements.

In making these experiments, I have established a fact of great pathological importance. It is generally known, and verified by daily observation, that compression of one hemisphere induces paralysis of that side opposite to the compressed hemisphere. This condition is most frequently attended with loss of both sensation and motion ; but, in certain cases, there is loss of only one of these functions. The anatomical researches of Gall and Spurzheim, by making better known the crossings of the pyramidalia at the anterior face of the medulla, and their apparent continuation with the radiated fibres of the corpora striata, rendered it very probable that the transmission of injurious effects from the compression takes place through the crossing roots of the pyramidalia.

I was desirous to ascertain, by experiment, if this idea was well

founded. For this object, I divided directly one of the pyramidalia in two living animals, reaching it through the fourth ventricle. I could not remark any sensible lesion in the movements; particularly no paralysis ensued, either on the wounded or opposite side. I did more; I divided entirely, and across, the two pyramidalia about the middle of their length, and no apparent derangement in the motions followed. I observed only a little difficulty in walking forward. The section of the posterior pyramidalia does not produce any visible alteration in the general movements. To produce paralysis of half the body, it is necessary to divide half the medulla oblongata, and then the corresponding part does not become absolutely immovable, for it presents irregular movements; it does not become entirely insensible, for the animal moves its limbs when pinched. But this half becomes incapable of executing the mandates of the will.

Of the Attitudes and Motions in different Ages.

From the embryo state to the eighteenth or twentieth year, the bones are continually changing their form, volume, &c. Of course, during all the time that the bones are altering their form, the attitudes and motions must exhibit changes analogous to those which take place in the skeleton. We have already seen that the muscles and muscular contraction are very much modified by age: these circumstances have all an influence upon the motions. Ordinarily, by the twentieth to the twenty-second year, the increase of the long bones is terminated, but they continue to increase in thickness until the adult age is completed, after which all increase ceases, and the changes which then take place in the bones, even to the most advanced old age, only relate to the nutrition of these organs, and their chemical composition.

The situation of the fœtus in utero depends on circumstances but imperfectly understood. For the most part, its head is directed below; this arises probably from its weight; but why the occiput corresponds almost always to that part of the pelvis which is above the acetabulum, or why it sometimes happens that the breech is found below, we are entirely ignorant.

The thighs in the fœtus are bent upon the abdomen, and the legs upon the thighs; the arms are crossed on the anterior part of the trunk, and the head inclined upon the breast, so that it occupies the least possible space. This does not depend upon muscular contraction; it is the effect of the tendency in the muscles to relax themselves; at a more advanced age, we often take this position when we wish to put all the muscles in a state of repose.

At the end of four months, the child begins to execute partial motions, and, perhaps, some slight motions, which displace the body wholly. These motions are irregular, arising at various periods, and continue until the end of pregnancy, and are frequently exerted by the inferior extremities, as can be distinguished at those points where they are felt. We cannot suppose that they depend upon the will, no intelligence at the time existing; this is also ev-

ident from the fact that acephalous infants, that is, those which have no brain, exhibit these motions the same as the most perfectly-formed children.

The newborn infant is incapable of assuming any particular position, but passively preserves that which is given to it; we, however, perceive that lying upon its back is the most agreeable, and is, no doubt, most favourable to the feeble state of its muscular system. The extremities move with facility, but its physiognomy is without expression. At the end of two or three months it changes its positions of its own accord. It lays on its side or face, turns its head, and the motions of its limbs become more various and powerful. It seizes objects with more strength when they are presented to it, and carries them to its mouth. When it sucks, it compresses with force the breast of its nurse, &c., but it remains long incapable of supporting itself upon its feet, or even of sitting. The following are the reasons of this: the head, being proportionally large and heavy, and not supported by any adequate muscular effort, falls forward; the weight of the viscera of the chest, and especially of the belly, is proportionally great; the vertebral column presents but one curve, the convexity of which is behind. The posterior muscles of the trunk are too weak to resist the disposition in the vertebral column to fall forward; besides, the spinous processes not being developed, the arms of the lever by which they act are very short, a circumstance most unfavourable to their action. The pelvis is very small, and, being very much inclined forward, does not support the weight of the abdominal viscera. The inferior extremities are but little developed, and are too weak to sustain the weight of the trunk; every kind of progression is therefore impracticable.

Soon, however, the infant, by using both its superior and inferior extremities at the same time, is able to transport itself over short spaces. From this circumstance, the extravagant idea has been advanced that man is naturally a quadruped, and that standing upon two feet is the result of living in a state of society. If there were any foundation for this idea, these organs in the adult would resemble those of the infant, which, as we have before seen, is not the case.

Towards the end of the first year, or at the commencement of the second, in consequence of the development of the bones, muscles, &c., and of the alteration in the proportional volume of the head and abdominal viscera, the infant becomes able to stand, but is still unable to walk; it soon acquires this power by taking hold of objects which are near it. At last, however, he walks alone, though his gait is tottering and uncertain, the body losing its balance by the slightest force. Walking is the first kind of locomotion which he is able to exert; it is generally a long time before he is able to run, or to make even inconsiderable leaps; but as soon as the different progressive motions become more firm and steady, he is in continual motion; he acquires agility and address, and a taste for the various sports of children, which almost al-

ways, especially in boys, serve to exercise the organs of locomotion and intelligence.

In a physiological point of view, the sports of children are well worthy of notice. When they are examined with attention, they will be found to mimic the actions of manhood. We may also remark the same feature in the sports of the young in other animals, which are generally imitations of those actions which their instinct will afterward impel them to repeat.

In the sports of infants, we must not confound those which are purely instinctive with those which are dependant on imitation.

From youth until the adult age, and even beyond it, all the phenomena which relate to the attitudes and movements of the body are in perfection; but with the approach of old age, they undergo a remarkable alteration, which arises from a diminution of the power of muscular contraction. The action of the muscles at this period is imperfect and tremulous, which is very apparent in the attitudes and motions. The old man, whether walking or standing, is bent forward; the pelvis is bent upon the thighs, these upon the legs, and the legs inclined forward upon the feet. This state of half flexion tends to weaken still more the power of the muscles, which have not sufficient energy to preserve the erect posture of the body. The old man endeavours to make up in some degree for these defects by means of a cane, which enlarges the base of support, and transmits directly to the ground the weight of the superior parts of the body. In very advanced old age, the motions become extremely difficult, and sometimes entirely lost.

Relation of Sensations to the Attitudes and Motions.

The sensations and motions have a reciprocal and manifest influence upon each other. Vision contributes to the fixedness of the greater number of the attitudes of our body; by it we judge of our comparative position with surrounding objects. When we are deprived of this means of judging of our equilibrium, as when we are on the top of a high edifice, or upon other elevated places, where we are only surrounded by the air, the position of the body becomes uncertain, and sometimes we are totally unable to preserve it. The utility of vision is still more apparent when the base of support is very narrow. A rope-dancer cannot preserve the erect posture unless his sight be constantly occupied with the position which he wishes to preserve, so that the perpendicular, which falls through the centre of gravity, may pass directly to the base of support. Whatever may be the attitude which we assume, it is very uncertain unless we employ vision; this is sufficiently evident in the postures and attitudes of blind persons.

If sight be of great assistance in the different attitudes, with much more reason must it be useful in the various partial movements and locomotions. Indeed, distinct vision favours our motions; it is that which gives to them their requisite precision and rapidity; in almost every instance it directs them. If we bandage the eyes of any active man, he instantly loses all his agility,

his gait is timid and tottering, especially if he be in a place with which he is not familiar. All his motions have the same character. The same phenomena occur in blind persons, who are readily recognised by the slight movements they execute, especially those which are not familiar to them. The absence of vision induces an indisposition to motion; the use of this sense, on the other hand, excites our activity; every one must be conscious of an instinctive desire of touching those objects which he sees for the first time.

A consideration of the relations between vision and motion leads us to observe that those motions which are destined to express our intellectual and instinctive operations, which are included under the generic name of *gestures*, may be divided into those which arise from organization, and, of consequence, must exist in man, in whatever condition he is found, and those which arise from the social state, and become improved with it.

The first are destined to express our most simple wants and most vivid internal sensations, as joy, grief, and fear, &c. Thus, in the expressions of the animal passions, gestures are to the other motions what the cry is to the voice. We observe them in those persons who are blind from their birth, in the idiot, and the savage, as well as man in a civilized state, enjoying every physical and moral advantage.

The second kind of gestures can only exist in a state of society, require vision and intelligence, and are not observed in those who are blind from their birth, or in idiots, savages, or in those individuals who have lived in an insulated state. They may be called *acquired* or *social gestures*, from their analogy with the acquired voice. It is extremely probable that, if we could restore sight to a person who had been blind from birth, we should enable him, at the same time, to acquire those particular gestures of which we are now speaking.

It may be said that the gestures of a person born blind are like the voice of a person born deaf. These two phenomena, under these two different circumstances, are made to supply each other's place. Thus deaf mutes make a continual use of gestures, and carry this mode of communicating their thoughts to a wonderful degree of perfection. The voice, on the other hand, is the only means of expressing their thoughts which are employed by the blind; from this arises their fondness for music and conversation, and the peculiar accent which they give to their voice.

Hearing has some influence upon the motions. This sense often concurs with vision in directing, and particularly in measuring them; thus causing them to return after equal intervals, and producing a certain number in a given time, as we observe in dancing and marching. It has been long remarked that motions executed by the sound of music are less fatiguing than without it. This arises from the regularity with which the muscles contract and relax alternately, the period of repose be-

ing equal to that of action. It may also be remarked that music excites us to motion.

The relations of smelling and tasting with the attitudes are too unimportant to attract much attention. With respect to touch, it is so intimately connected with muscular contraction, that without it this sensation cannot take place; and it is easy to see that it is intimately connected with all the phenomena which depend upon muscular contraction.

The internal sensations have no less influence upon the different attitudes and motions of the body than the external. Who cannot distinguish, by his gait and gravity, a man suffering pain, or any other vivid sensation? We can even determine, with considerable certainty, the particular seat of the painful affection by the arrangement of the body or the kind of gestures which the patient employs. In a violent colic, *e. g.*, the chest is thrown forward upon the pelvis, and the hands pressed upon the belly; a violent pain in the side naturally induces us to incline to the side affected; and the stone in the bladder compels the patient frequently to assume a particular attitude.

We thus see the influence of the sensations upon the attitudes and motions, and these, again, react, by influencing the sensations. The different attitudes are favourable or unfavourable to the development of the external sensations. There are particular motions, peculiar to each sensation, which favour its action; besides, nearly all the senses have particular muscles, which favour their action, and which constitute an essential part of the apparatus, as we observe in the eye and ear.

Relations of the Attitudes and Motions to the Will.

The attitudes and motions which we have described have the epithet *voluntary* applied to them, because they are said to be under the immediate influence of the will. This assertion is true to a certain extent, but in some respects it is not; we shall therefore farther investigate this point.

In consequence of the determination of the will a motion is produced, and there can be no doubt that the will causes the development of it; but all the phenomena which take place in the production of this motion are not under the control of the will. I can move my hand or arm, but I am unable to contract, singly or together, the muscles of this part if I have not an idea of the motion to be produced. This is equally true of all those muscles which we consider entirely submissive to the will. If we should undertake to contract the *obturator externus*, or any other muscle which does not produce of itself any determinate motion, we should find that this would be impracticable.

We may, then, assert that the cause determining the motion is the will, but that the production of the muscular contraction necessary to execute this motion is not dependant upon that cerebral action called the will, but is purely instinctive.

From these considerations, it may be inferred that the *will* and

the *action of the brain*, which produce directly the contraction of the muscles, are two distinct phenomena. But the direct experiments of modern physiologists, and what has already been said respecting the influence of the cerebrum and cerebellum on the movements, have clearly established this truth. These experiments have clearly demonstrated that, in man and mammiferous animals, the will more particularly resides in the cerebral hemispheres. The direct cause of the movements appears, on the contrary, to have its seat in the medulla spinalis. If we separate the spinal marrow from the rest of the brain by an incision near the occiput, we prevent the will from determining and directing these motions, though they are, nevertheless, executed. As soon, however, as the separation takes place, they become irregular in extent, rapidity, duration, and direction.

I have recently had under my observation a patient, who presented the singular spectacle of the complete separation of the will, and the forces which preside directly over the movements, of which I will give a brief account.

M. *** was thirty-six years of age, of an agreeable countenance, cultivated mind, and easy, pleasant manners, but of great nervous susceptibility. His life had been that of a man of the world until his marriage, about ten years before. At this period he was compelled to devote himself to business. He experienced severe disappointments, and was afterward very much distressed in consequence of his wife being attacked with a mental disease immediately after her first confinement. He did not leave her an instant during her whole indisposition; he accompanied her in journeys, and constantly witnessed, for more than a year, all the intellectual aberrations and convulsive motions of a person to whom he was tenderly attached. The complete cure of the wife relieved the moral torture of the husband; but, instead of giving himself up to the joy which might have been anticipated from such an event, he became gloomy, silent, and at last presented all the symptoms of true melancholy. He believed his fortune inevitably lost; that he had become an object of general animadversion, of the suspicions of the police, and the railleries of the public. His mind was sane on all other subjects. He was induced to travel, visit the watering-places, and was subjected to various therapeutic treatment, but without success.

Things were in this state, when, in the month of September, he was seized with a stiffness of his right leg and thigh, which caused him to halt in walking. A few days afterward the other limb became affected in the same way; after this he lost all command over his voluntary motions. The muscles of voluntary motion were, however, far from being paralyzed; but they were given up, as it were, to their own control, often for hours. The unfortunate young man, during this time, was compelled to execute the most irregular movements, to assume the most extraordinary attitudes, and make the strangest contortions. It is impossible for language to describe the multiplicity and eccentricity of his move-

ments and positions. If he had lived in an ignorant age, he would, no doubt, have been supposed possessed; for his contortions were so remote from the common movements of man, that they might easily have been regarded as those of a demon. It was remarkable that, in the midst of these contortions, his form, slender and supple, was sometimes pushed forward, at others thrown to one side or backward, yet, like certain tumblers, he never lost his equilibrium. In the multiplicity of his singular attitudes and movements, for many months, he never fell.

In certain instances, he returned to the ordinary movements; thus, without the will in the slightest degree, he would rise and walk rapidly until he encountered some solid body which opposed his course. Sometimes he would go backward with the same rapidity, until he was stopped in the same way.

He was often observed to execute certain movements without the power of performing others. Thus his arms and hands were frequently obedient to his will; still more frequently the muscles of the face, and speech. He could sometimes walk backward when it was impossible to go forward; and he then used this retrograde movement to direct himself towards those objects that he wished to attain. But these movements, that may be called automatic, never lasted a whole day; he often had considerable intervals of relief between the paroxysms, and his nights were always tranquil.

So long as the muscular efforts were violent, the perspiration was copious; when they ceased, he did not experience a sense of fatigue proportioned to the intensity of the muscular efforts; as if the intellectual exertion that we make to excite our movements is that which chiefly conveys to us the sense of fatigue.

If the action of the brain which produces muscular contraction be a phenomenon distinct from the will, we may easily conceive why, in certain cases, the motions are not produced, although the will commands them; and why, under different circumstances, very extensive and powerful motions take place without any participation of the will, as we frequently see in diseases. For the same reason, we may conceive why it is very difficult, and often impossible, for us to assume a new attitude, or to execute a motion for the first time; why the arts of dancing, fencing, &c., which depend upon the rapidity and precision of our motions, are only acquired by long exercise; why, in a word, it frequently happens that we execute certain motions more perfectly when our mind is not fully directed to it, than when our whole attention is concentrated upon it.*

Relations of the Attitudes and Motions to Instinct and the Passions.

We have seen that a great number of what are called the *voluntary motions and attitudes* are under the dominion of *instinct.*

* This doctrine has been confirmed by the experiments of Dr. Wilson Phillip.—*Philos. Trans.*, 1815.

There are a great number of attitudes and motions, both partial and general, which essentially depend upon it.

All the instinctive sentiments which essentially depend upon organization, such as sadness, fear, joy, hunger, thirst, when carried to a certain degree, induce attitudes and motions which are peculiar to them, and indicate their existence. It is the same in the natural passions, and all the instinctive phenomena which the social state develops.

Most of the passions impel us to move, and increase very much the intensity of muscular contraction, as we observe in excessive joy and anger, and, in some instances, in fear. Others of the passions stupify us, and render all kinds of motion impracticable, such as great chagrin, and certain sorts of terror; often extreme joy produces the same effect. This is the reason why the pantomimic art is exercised with so much success in exhibiting the violent passions.

Relations of the Motions to the Voice.

These are intimate, inasmuch as both phenomena are the immediate effects of muscular contraction; with this difference, that in the voice we hear the effect, and see it in the motions.

There are certain motions which essentially depend upon organization; they in this respect resemble a *cry*. There are modes of voice which are acquired in social life; a great number of motions are acquired in the same manner. The voice and motions unite in the production of speech; these two are our principal and almost only means of expression. They aid each other, and sometimes supply each other's place. A man who finds difficulty in expressing himself uses much gesticulation, but the reverse is generally the case with those whose elocution is easy. In the expression of the more powerful passions they are united. It is rare that, in expressing strong feelings, we do not unite gesture with speech.

It has been remarked, that the modifications which the motions and voice undergo by age are very analogous; we shall find the same result, if we study the manner in which they are modified by age, sex, temperament, and habit.

We shall finish, with these considerations, the description of the functions of relation. These functions possess the common character of being suspended, or remaining, during certain intervals, in a state of repose, or *sleep*. It would seem, therefore, proper that the history of sleep should immediately follow the description of the functions of relation. But, as the nutritive and generative functions are both influenced by sleep, we prefer entering upon the examination of them first.

CHAPTER XIII.

OF THE NUTRITIVE FUNCTIONS.

Our bodies are incessantly undergoing changes in their dimensions, form, structure, &c., from the moment of their formation until their existence ceases. We are constantly losing in different ways, as perspiration, urine, respiration, &c., a part of the elements which compose us. These losses, which amount in the day to many pounds, weaken us, and we should soon die, did we not repair them by means of aliments and drinks. Again, our temperature does not vary with that of the bodies which surround us. We resist equally great cold or heat; we have thus within a peculiar source of heat, and the means of cooling. We may add that our bodies, during life, do not undergo that rapid decomposition which they exhibit as soon as death has taken place. Thus, it appears that there is going on a continual intrinsic movement, by which our organs appear, on the one hand, to use up and destroy themselves; and, on the other, to repair themselves and acquire new power; and that this renewal of our constituent elements is one of the fundamental acts of life.

This intrinsic movement is not what the imagination of physiologists have suggested, nor, as the ancients supposed, a renewal of the body in seven years. But its reality is established by a great number of facts and experiments. We are far from fully comprehending this phenomenon, no doubt very complicated, inasmuch as it is connected with all the physical changes of our organs, the texture of which is so various and delicate, and the elements so different and numerous.

This phenomenon supposes, 1st. Easy communications always open between the most concealed parts of our organs, and the natural passages for excretion and reparation. 2d. A powerful mechanical force, keeping in continual motion our different elements. 3d. It implies that our bodies should be the seat of innumerable chemical transformations, which must follow with more or less vigour the laws of affinity and proportions.

It is easy to point out the difficulties of all kinds that we encounter in studying the nutritive functions. At each step it will be necessary to apply chemical, physical, and mechanical principles; or what is, perhaps, still more difficult, to know when these principles are not applicable; that is, to distinguish the phenomena purely vital from those that are simply physical. But the insurmountable difficulty, if we may use the expression, will be found in the manner that all the nutritive acts are connected together and confounded. The arbitrary classification that we are obliged to establish, in order to facilitate the study, is the less advanta-

geous, as it does not rest on a complete knowledge of the different functions, and that we are still very far even from having arrived at anything entirely satisfactory as relates to the principal.

But in following undeviatingly the route of observation and experiment, and keeping to a simple expression of facts, we arrive at results that are not without importance.

These functions are six in number, viz., 1st. Digestion. 2d. Absorption, and the course of the chyle. 3d. The course of the lymph. 4th. The course of the venous blood. 5th. Respiration. 6th. The course of the arterial blood.

After a description of these functions, and of their relations to each other, and to those of relation, we shall study the different secretions; and, lastly, point out what is known of the molecular action that takes place in the depths of the organs, and which, in a restricted sense, is usually called *nutrition.*

OF DIGESTION.

The immediate object of digestion is the formation of the chyle, a substance which is destined to repair the loss which the animal economy is constantly suffering. The digestive organs contribute also in several other ways to nutrition. To form the chyle, the digestive organs act upon the aliments; crush and decompose them, separating that part which is crude and useless from that which is nutritive and useful; which ultimately forms the chyle, and is conveyed to the most remote parts of the tissues.

The object of digestion is, then, chemical, inasmuch as it extracts from the aliments the material destined to form the chyle, when combined with certain other elements.

Organs of Digestion.

If we judge of the importance of a function from the number and variety of the organs which concur to effect it, digestion will occupy the first rank. No other function in the animal economy presents an apparatus so complicated.

The organs of digestion may be regarded as a chemical apparatus arranged with great care, which acts of itself upon certain substances when placed within its range. There is a grinding machine, superior in its arrangements, in many respects, to those used in the mechanic arts to obtain similar results; an extensible and contractile vessel, intended to hold these alimentary substances during a certain time; a long, straight tube, through which the substances pass rapidly; another tube, much longer, and convoluted upon itself, through which the aliments pass more slowly. In these different cavities there are the orifices of innumerable small tubes, which pour out those re-agents which are necessary to the process.

There exists an evident relation between the food of the animal and the digestive apparatus. If the aliments differ essentially in their nature from the elements which compose the animal; if, for example, the food is *herbaceous,* the apparatus will be of large di-

mensions, and complicated. If, on the other hand, the animal is nourished by flesh, its digestive organs will be less numerous and more simple, as we see in carnivorous animals. The food of man being both animal and vegetable, he preserves a medium between the complicated digestive apparatus of herbivorous, and the simple apparatus of carnivorous animals, and is, therefore, called *omnivorous*. It seems hardly necessary to remark, that there are a great number of substances which are used as aliments by animals which are of no utility to man in this respect.

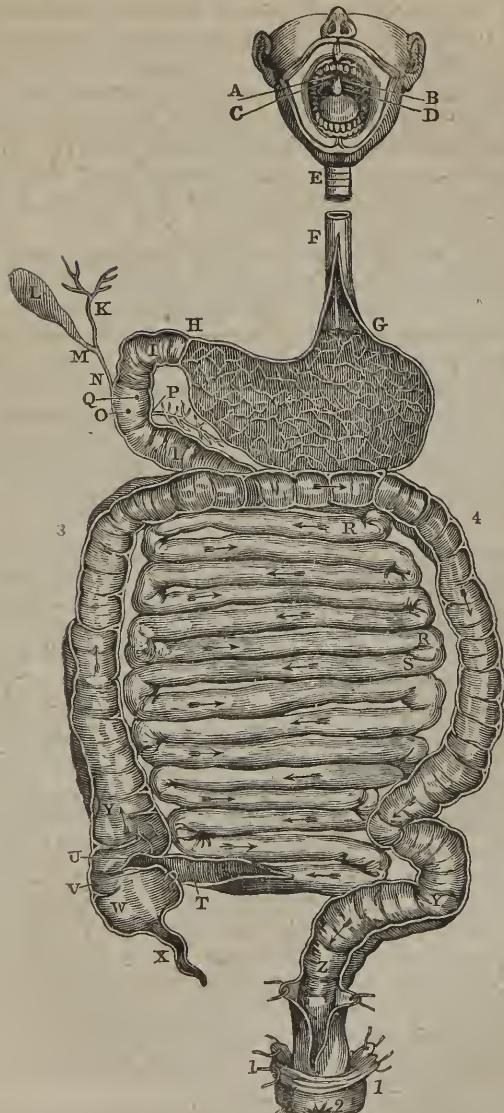
We may describe the digestive apparatus as a long canal, convoluted upon itself, large in some places and small in others; susceptible of being enlarged and diminished, and into which are poured a great quantity of fluids, by means of certain ducts. Anatomists divide the digestive organs into several portions: 1st, the mouth; 2d, the pharynx; 3d, the œsophagus; 4th, the stomach; 5th, the small intestines; 6th, the large intestines; 7th, the anus.

[The diagram opposite will clearly illustrate the different portions of the alimentary canal, its course, and arrangement.

The parts above the diaphragm are the mouth and tongue. A, the soft palate; B, the anterior pillar; C, the posterior pillar: the space between them is called the fauces. E is the trachea, a portion of which, with the œsophagus behind it, are removed, to shorten the diagram. F is the œsophagus; G is the cardiac orifice of the stomach, and is placed below the diaphragm. The canal below this point consists of the stomach and small intestines, which, from having considerable extent of motion, are called *floating viscera*, and the large intestines, which are more strictly bound down, and describe a fixed course. H is the pyloric orifice of the stomach. The space between G and H shows the internal surface of the stomach, a portion of this organ, and of the duodenum, I I, being removed for this purpose. K is the hepatic duct; L, the gall-bladder and its duct, which will unite at M, and form the common duct N, which enters the duodenum at O. P indicates the pancreatic duct, which enters the duodenum at Q. R R are the folds of the jejunum; S S, those of the ilium. U, the part at which the small intestines terminate in the large, and here form the ileo-cœcal valve: it is slit open, to show the structure. W is the cœcum; X, the vermiform process. From U to 3 is the ascending portion of the colon; from 3 to 4, the transverse portion or arch of the colon; from 4 to Y, the descending portion of the colon; Y, the sigmoid flexure of the colon; Z is the rectum; 1 1, the levatores animuscles; 2 is the anus.]

The walls of this canal are formed by two membranous laminæ through its whole extent. The internal lamina, which is destined to be in contact with the aliments, consists of a mucous membrane, the aspect and structure of which vary in different portions of the canal: it is different in the pharynx from the mouth—in the stomach from the œsophagus, &c. At the lips and anus, this membrane is lost in the skin.

Course and Arrangement of the Alimentary Canal.
(Fig. 33.)



The second lamina, which forms the wall of the digestive canal, is *muscular;* it consists of two planes of muscular fibres; the one longitudinal, the other circular. The arrangement, thickness, and nature of the fibres differ in the mouth, œsophagus, large intestines, &c.

A great number of blood-vessels are sent to, and arise from this canal, but the abdominal portion receives incomparably the largest part. The superior part only receives a sufficiency to answer the purposes of nutrition, and the inconsiderable secretion of which it is the seat; but the number and volume of the vessels which appertain to the abdominal portion indicate that it is intended as the agent of a considerable secretion. The chyliferous vessels take their rise exclusively from that portion of the canal called the small intestines.

The nerves are distributed over the canal in a reversed order from the blood-vessels; that is, the cephalic, cervical, and pectoral parts receive more than the abdominal portion, with the exception of the stomach, where the nerves of the eighth pair terminate. The remainder of the canal does not receive scarcely a branch of the cerebral nerves. The only nerves which can be distinguished proceed from the sub-diaphragmatic ganglions of the great sympathetic. We shall see, by-and-by, the relation which exists between the mode of distribution of the nerves, and the functions of the superior and inferior portions of the digestive canal.

The organs which pour out fluids into the digestive canal are, 1st. The *digestive mucous membrane* itself; 2d. The *insulated follicles*, which are scattered in great numbers through the whole extent of this membrane; 3d. *Agglomerated follicles*, which are met with at the entrance of the œsophagus, between the pillars of the veil of the palate, and sometimes at the junction of the œsophagus and stomach; 4th. The *mucous glands*, which exist in considerable numbers in the walls of the cheeks, the arch of the palate, near the œsophagus; 5th. The *parotid*, *submaxillary*, and *sublingual glands*, which secrete the saliva that is poured into the mouth; the *liver* and *pancreas*, the first of which pours out the bile and the second the pancreatic juice, by distinct ducts, into the superior part of the small intestines, which is called the *duodenum*.

All the digestive organs contained in the abdominal cavity are immediately covered, in a manner more or less complete, by a serous membrane, called the *peritoneum*. This membrane, from the manner in which it is arranged, and its physical and vital properties, serves important purposes in the act of digestion, either by preserving in the organs their respective relations, or by favouring their variations of volume, and preventing any friction upon each other or the neighbouring parts.

We shall give the necessary details concerning the apparatus of digestion, after we have explained their functions. We shall confine ourselves at present to some remarks on the organs of

digestion, considered during life, but at the time when they are not executing their peculiar functions.

Remarks on the Digestive Organs of Man and living Animals.

The surface of the mucous membrane of the digestive canal is always lubricated by a stringy, viscous substance, which is poured out more or less abundantly. It is observed in the largest quantity in those parts where no follicles exist; a circumstance which seems to show that these are not the only secretory organs. One part of the substance, generally called mucus, continually evaporates, so that there constantly exists a certain quantity of vapour in each part of the digestive canal. The chemical nature of this substance is not well known. It is transparent, with a slight grayish tint; it adheres to the membrane which forms it; its taste is salt, and the application of certain tests shows that it is acid. Its formation continues some time after death takes place. That which is formed in the mouth, pharynx, and œsophagus is propelled into the stomach, and mixed with the secretions of the mucous glands and saliva, by the action of deglutition, which frequently takes place. It would seem, from this, that the stomach, when there are no aliments in it, contains a considerable quantity of this mixture of mucus, follicular secretion, and saliva. This is a point, however, which is not confirmed by the experience of most persons. Nevertheless, it is evident that this exists in some persons, their stomach being known in the morning to contain several ounces of this mixture. In some cases it is frothy, very viscid, and slightly clouded, holding suspended *floculi* of mucus. Its taste is plainly acid, but not disagreeable; it is sensibly perceived by the throat, and acts upon the teeth, so as to diminish the polish upon their surface, and to prevent their gliding easily upon each other. This fluid, when applied to the tincture and paper of litmus, causes them to turn red.*

Under different circumstances, in the same individual, with the same appearances as relates to colour, transparency, and consistence, this fluid, when taken from the stomach, has neither the taste nor other properties of acids; sometimes it is slightly salt. Neither a solution of potash, nor sulphuric or nitric acids, produce any apparent effect upon it.

One of my former pupils, Dr. Pinel, who possessed the faculty of vomiting at will, informed me that he frequently evacuated from the stomach, in the morning, three ounces of this fluid. Some of this liquid was examined by M. Thenard, who found it composed of a large quantity of water, some mucus, and some salts, the base of which were soda and lime; there was no acidity perceptible either by the tongue or re-agents. The same physician recently sent me about two ounces of a fluid obtained in this way. M. Chevreul analyzed it, and found a large proportion of water, a considerable quantity of mucus, the lactic acid of Berze-

* *Vide* Experiments on Digestion in Man, by S. de Montegre, 1804.

lius, a small quantity of animal matter, soluble in water, but insoluble in alcohol, some hydro-chlorate of ammonia, hydro-chlorate of potash, and hydro-chlorate of soda.

With respect to the quantity of this fluid, M. Pinel observes, that if he had swallowed a mouthful of any aliment, he could obtain it in any quantity, in a short time, even to half a pound. M. Pinel thinks that the taste of this fluid varies according to the sort of aliment he had used the night before.

When we examine the bodies of persons who die suddenly, and whose stomachs had not recently received either food or drink, this organ is only found to contain a very small quantity of acid mucus adhering to its walls, and of which that part which is found in the pyloric portion of the viscus appears reduced into chyme. It is, then, extremely probable that the fluid which passes into the stomach is digested, as an alimentary substance, which is the reason of its not accumulating.

In animals the organization of which resembles man, as dogs or cats, we do not find any fluid in the stomach, after some days of absolute abstinence; we only find a little viscid mucus adhering to its walls, at the splenic extremity. This substance has a very great analogy, in its physical and chemical properties, with what we find in the stomach of man. But if we cause animals to swallow a body which is not susceptible of being digested, a pebble, for example, there is formed, after some time, in the cavity of the stomach, a mucous, acid fluid, of a grayish colour and sensibly salt taste, which resembles, in its composition, the mucus we often meet with in man, the analysis of which, by M. Chevreul, has already been given.

This fluid, which is composed of the mucous secretions of the mouth, pharynx, œsophagus, and stomach, with the fluid secreted by the follicles of these parts, and the saliva, has received from physiologists the name of gastric juice, to which they have attributed peculiar properties.

In the small intestines there is formed a large quantity of mucous substance, which remains constantly attached to their internal walls. This differs little, in its sensible qualities, from that which we have spoken of above; it is viscid, ropy, and somewhat salt and acid in its taste; it is very rapidly renewed. If we lay bare the mucous membrane of this intestine in a dog, and remove from it the mucus which will be found there, absorbing it with a sponge, a minute will scarcely pass before it is replaced. We may repeat this experiment as frequently as we choose, until the intestine becomes inflamed, in consequence of the contact of air and other foreign bodies. When the mucus penetrates into the cavity of the small intestines, it is in the form of a pulpy, grayish, opaque matter, which has the peculiar appearance of a particular chyme.

The bile and the fluid secreted by the pancreas are poured out into that portion of the canal which is called the *duodenum*. I believe that no one has ever observed in man, during life, the

manner in which the bile and pancreatic juice are poured out. In animals, dogs, for example, this fluid oozes out at intervals, that is, about twice in a minute we see spring from the orifice of the biliary duct a drop of bile, which spreads itself uniformly over the surrounding parts, which are already impregnated by it.

Thus there is always found in the small intestines a certain quantity of bile. The oozing of the fluid formed by the pancreas takes place in a similar manner, but much more slowly. A quarter of an hour often elapses before we see a drop of this fluid pass out from the orifice of the duct, which pours it into the intestines. I have, however, in some instances, observed it to ooze out with much more rapidity.

The different fluids which are deposited in the small intestines, viz., the chyme which comes from the stomach, the mucus, the follicular fluid, the bile and pancreatic juice, are mixed together, but, in consequence of its properties, and perhaps of its proportion, the bile predominates, and gives to the mixture its colour and taste. A great part of this mixture descends towards the large intestines. In its passage its consistence is increased, and it becomes of a bright yellow colour, though at first of a deep yellow, and afterward green. There is, however, a great difference in this respect in different individuals.

In the large intestines, the mucous and follicular secretion appears to be less active than in the small intestines. This admixture of fluids, after it has arrived at the large intestines, acquires a much greater degree of consistency, and a fetid odour, analogous to that of other fecal matter.

The knowledge of these facts enables us to conceive how a person who has made no use of aliments continues to evacuate the canal; and how, in some diseases, the quantity discharged is very great, although the patient may have been for a long time deprived of every alimentary substance, even liquid. Near the anus there are found follicles which secrete an oily fluid, which has a strong and peculiar odour. We find, almost constantly, gas in the intestinal canal; the stomach contains very little. The chemical nature of this gas has not yet been examined with care, but, as the saliva which we swallow is always impregnated with atmospheric air, it is probable that it is this gaseous fluid more or less modified; I have ascertained, by experiment, that it is partly composed of carbonic acid. The small intestines contain a very small quantity of gas; it is a mixture of carbonic acid, azote, and hydrogen. The large intestines contain carbonic acid, azote, and hydrogen, and sometimes carburetted, and at others sulphuretted, hydrogen. I saw twenty-three hundredths of this gas in the rectum of a criminal lately executed, though the large intestines did not contain any fecal matter.

We may ask, What is the origin of these gases? Are they derived from the external air, or secreted by the mucous membrane of the canal, or are they results of the chemical action of the substances contained in the canal? We shall examine these ques-

tions hereafter ; in the mean time we will remark, that we are in the habit of swallowing much more atmospheric air than we are aware of.

The muscular coat of the digestive canal, in relation to the different modes of contraction which it excites, must be noticed. The lips, the jaws, generally the tongue and the cheeks, move by a contraction, perfectly analogous to that of locomotion. The veil of the palate, the pharynx, œsophagus, and, in some particular circumstances, the tongue, exhibit motions which have a manifest analogy to muscular motion, but differ from it in being executed without the participation of the will. I have, however, seen some persons who could move the veil of the palate, and the superior parts of the pharynx, at will.

I would not, however, be understood to say that the motions of the parts of which I have been speaking take place without nervous influence, for experience proves the reverse of this. If, for example, we divide the nerves which pass to the œsophagus, we deprive this part of its contractile power.

The muscles of the veil of the palate, those of the pharynx, and two thirds of the superior part of the œsophagus, do not act as digestive organs, except when they thrust forward substances from the mouth towards the stomach. The inferior third of the œsophagus presents a peculiar phenomenon, which it is important to understand. This is an alternate contraction and relaxation, which continually take place. This begins at the point where the two superior thirds of the canal unite with the inferior third. It is prolonged, with a certain degree of rapidity, to where the œsophagus is inserted into the stomach. Once produced, it continues for an indefinite time; its medium duration is about thirty seconds. While the inferior third of the œsophagus is thus contracted, it is as hard and elastic as a tense cord. The relaxatian which succeeds this contraction occurs suddenly and simultaneously, through the whole extent of the contracted fibre, but in some cases it seems to take place from the superior towards the inferior part. In a state of relaxation, the œsophagus presents a remarkably flaccid appearance, which is strongly contrasted with its state of contraction.

This motion of the œsophagus depends upon the nerves of the eighth pair. When we divide these nerves, the œsophagus no longer contracts, but it does not remain in the remarkable state of relaxation which we have described. Its fibres, independently of this nervous influence, continue to contract themselves with a certain force, and the canal remains in an intermediate state between contraction and relaxation. The emptiness or distension of the stomach has an influence upon the intensity of the contractions of the œsophagus.*

* The alternate motion of the inferior third of the œsophagus does not take place in the horse; but in this animal the pillars of the diaphragm have a particular action on the cardiac extremity of this duct, which does not take place in those animals which vomit easily. See the detail of experiments made by me on this subject, and the Report of the Committee of the Institute in the "Bulletin de la Societée Philomatique, Année 1815." Since

From the lower part of the stomach to the end of the rectum the intestinal canal exhibits a mode of contraction which differs, in almost every respect, from that of the part of the canal which is above the diaphragm. This contraction is always made slowly and irregularly; an interval of an hour often takes place without our being able to perceive any trace of it; at other times, many portions of it contract at a time. It appears very little under the influence of the nervous system; it will continue, for example, in the stomach after we have divided the nerves of the eighth pair; it becomes more active by debilitating animals, and even by apparent death in some cases it becomes considerably accelerated by it; it remains even when the intestinal canal has been separated from the body. The pyloric portion of the stomach and the small intestines are the parts of the canal where this contraction takes place most frequently and regularly. This motion, which results from the successive or simultaneous contraction of the longitudinal and circular fibres of the intestinal canal, has been designated by different names by authors. It has been called *vermicular*, or *peristaltic* motion, and *organic sensible contractility*. Whatever it may be, the will does not exert any sensible influence upon it. The muscles of the anus contract voluntarily.

The super-diaphragmatic portion of the canal is not capable of undergoing any considerable dilatation. It is easy to see, by its structure, and the mode of contraction of its muscular coat, that it will not permit aliments to remain in its cavity, but that it is rather destined to transport these substances from the mouth to the stomach. The stomach and large intestines, on the other hand, evidently admit of great distension; the substances introduced into the canal also accumulate, and remain longer in them than in the other parts.

The diaphragm and abdominal muscles keep up a continual action upon the digestive organs contained in the abdomen. They exert upon these organs a continual pressure, which becomes sometimes very considerable. We shall see, below, how these two causes, singly or together, concur in the different acts of digestion.

Of Hunger and Thirst.

Before digestion in man and animals can take place, it is necessary that a certain number of actions should precede, by which the food is seized, triturated, and introduced into the stomach. This introduction necessarily ceases when the stomach is full, and ought only to take place to such an extent as will satisfy the demands of the economy; and, in general, it is best that it should

that period, I have examined with more care the œsophagus of the horse, and have remarked that its diaphragmatic extremity, for about eight or ten inches, does not contract like muscles. Galvanic irritation of the eighth pair of nerves produced no effect upon it. But it is very elastic, and keeps the lower extremity of the œsophagus so narrowly closed, that, even for a considerable time after death, it is difficult to introduce the end of the finger, and requires a strong pressure to force in air. This arrangement, I believe, is the true reason of the great difficulty of vomiting in the horse, so that he sometimes ruptures the stomach in his attempts to vomit.

not be done until the preceding digestion is terminated ; there are also other circumstances where it is injurious. It was, therefore, necessary that man and animals should be informed of the moment when it was proper to receive solids or liquids into their stomach, and of the circumstances in which it was improper. Nature has effected this important purpose by imparting to us many instinctive feelings, which inform us of the wants of the economy, and of the particular state of the digestive organs. These feelings vary according to our wants. They may be divided into those which excite us to use some particular substances, and into those which induce us to desire something remote and difficult to be obtained. The first relate to *hunger* and *thirst*, and the second to *satiety* and *disgust.*

Of Hunger.

The desire of solid aliments is characterized by a particular sensation in the region of the stomach, and some degree of debility. In general, this sensation is produced when the stomach has remained empty for some time. The intensity differs very much in different individuals, and even in the same individual at different times. With some, its violence is extreme ; with others, it is scarcely perceptible ; some never experience it, and only eat because the hour of repast has arrived ; many persons feel an oppression, more or less painful, in the epigastric region ; in others, there is a gentle heat in the same region, accompanied with yawning, and a particular noise, owing to the displacement of the gas contained in the intestines ; this noise is technically called *borborygma.* When this desire is not satisfied, it increases very much, and at last it becomes very painful ; and a sensation of general weakness and fatigue is induced, which may go to the extent of rendering locomotion difficult, and even impossible.

Authors distinguish hunger into local and general phenomena. This distinction is in itself proper, and may, perhaps, be advantageous to the student ; but have not mere gratuitous suppositions, the existence of which are barely possible, been described as the local or general phenomena of hunger? This is one of those points in physiology in which the deficiency of direct experiment is most palpably felt.

The contraction of the stomach has been reckoned among the number of the local phenomena of hunger. " The walls of the viscus, it is said, become thicker ; it changes its form and situation, and is drawn a little towards the duodenum. This cavity contains the saliva mixed with air, mucus and hepatic bile which has flowed back by the action of the duodenum. These different humours are accumulated in the stomach in proportion to the duration of the fasting. The cystic bile does not run into the duodenum, but remains in the gall-bladder, and is more abundant and black in proportion to the duration of the abstinence. There is a change in the order of the circulation of the digestive organs ; the stomach receives less blood, either in consequence of the flexuous

course of its vessels, then greater, because its coats are drawn together, or in consequence of the compression of its nerves from this contraction, the influence of which upon the circulation will be diminished. On the other hand, the liver, spleen, and epiploon, in receiving more blood, perform the office of a *diverticulum;* the liver and spleen, because they are less supported when the stomach is empty, and, therefore, offer a more free access to the blood; and the epiploon, because then its vessels are less flexuous," &c.* The most of these propositions are merely conjectures, and are nearly destitute of proof. They have been already, in part, refuted by Bichat, though some of the objections of this ingenious physiologist are themselves exposed to criticism. Not being able to enter into the details of this discussion, I shall only relate the experiments I have made myself on this subject.

After twenty-four, forty-eight, and even sixty hours of complete abstinence, I have never seen this contraction of the stomach, of which authors speak. This organ has always presented dimensions sufficiently large, especially at its splenic extremity. Until the expiration of the fourth or fifth day, I have not found the stomach to change its capacity, or to alter, even slightly, its position; even then the effects are not very remarkable, except the fasting has been rigorously observed.

Bichat thinks that the pressure sustained by the stomach when it is empty is equal to what it supports when it is distended by aliments, as the abdominal walls contract in proportion as the volume of the stomach diminishes. There is no difficulty in satisfying ourselves of the incorrectness of this opinion. If we introduce our two fingers into the cavity of the abdomen, after its walls have been divided, we shall find, by direct experiment, that the pressure upon the viscera of this cavity is in proportion to the distension of the stomach. If the stomach be full, the fingers will be pressed strongly, and the viscera will be forced through the opening; if it be empty, the pressure will be slight, and the effort of the viscera to escape trifling. We must not confound in this experiment the pressure exerted by the abdominal muscles, when they are relaxed, with that which is produced when they contract forcibly. Also, when the stomach is empty, all the reservoirs contained in the abdomen are more readily allowed to become distended with their natural contents. This, I believe, is the principal cause of the accumulation of the bile in the *vesicula fellis.* With respect to the presence of the bile in the stomach, which some persons suppose produces the sensation of hunger, I believe that, in certain morbid conditions, the bile is not introduced into this organ, though it may continue to be constantly thrown out into the small intestines.

The quantity of mucus existing in the cavity of the stomach becomes less as the abstinence is prolonged. My experiments on this point entirely agree with those of Dumas. With respect to the quantity of blood sent to the stomach when it is empty, from

* *Vide* Dictionnaire des Sciences, Medicales, article Digestion.

the size of its vessels, and the mode of circulation which takes place there, I am induced to believe that it receives less of this fluid than when it is distended with food; but, instead of differing in this respect from the other abdominal organs, it appears to me to be common to them all.

We include under the general phenomena of hunger a weakening and diminution of action in all the organs; the circulation and respiration become slower, the heat of the body less, the secretions diminish, and all the functions are performed with difficulty. It has been said, however, that absorption becomes more active; but there is no conclusive evidence of this.

Hunger must be distinguished from appetite, the inclination we have to prefer one sort of food to another. These sensations differ essentially from hunger, which is an expression of the true wants of the economy; they are peculiar, in a great degree, to civilization, habits, and certain ideas relative to the properties of aliments. Some arise from season and climate, and then they become as natural as hunger itself; such is the inclination we have for a vegetable diet in warm climates, or in the heat of summer.

There are some circumstances which render hunger more intense, and cause it to return after shorter intervals; such as the cold and dry air of winter, cold baths, dry friction of the skin, exercise on horseback, walking, fatigue of body, and, in general, all those causes which accelerate the action of the organs of nutrition, with which hunger is essentially connected. Some substances, when introduced into the stomach, excite a sensation analogous to that of hunger, but which, however, should not be confounded with it.

There are circumstances which diminish the intensity of hunger, and which retard the periods when it habitually manifests itself; such as the moisture or warmth of the climate, repose of the body and mind, the gloomy passions; in a word, all those causes which diminish the action of all the organs, and particularly those of nutrition. We also know that certain substances, when introduced into the stomach, prevent the action of the organs and cause the sense of hunger to cease, as opium and warm drinks, &c.

The causes of hunger have been, in turn, attributed to a great variety of circumstances; as the foresight of the vital principle, the friction of the walls of the stomach on each other, the mechanical action of the liver upon the diaphragm, the action of the bile upon the stomach, the acridity and acidity of the gastric juice, the fatigue of the contracted fibres of the stomach, the compression of the nerves of this viscus, &c., &c. Hunger is produced, like all other internal sensations, by the action of the nervous system, and it has no other seat than in this system itself, and no other causes than the general laws of organization. What proves the truth of this assertion is, that it continues often when the stomach is distended with aliment; and, again, it does not occur, al-

though the organ has been empty for a long time; in a word, it is governed by habit, so as to cease spontaneously when the hour of repast has passed. This is true, not only as relates to the sensation experienced in the region of the stomach, but also the general weakness which accompanies it, and which, of consequence, cannot be considered real, at least in the first instant when it is manifested.

Many authors confound hunger with the effects of a complete abstinence, prolonged until death is produced. We shall not follow their example in this respect. Hunger, considered as an instinctive phenomenon, belongs to physiology, but considered as a cause of disease, it pertains to pathology.

Of Thirst.

We give the name thirst to that sensation which induces us to desire drink. It differs in different individuals, and is not the same always even in the same person, at different times. In general it consists in a sense of dryness, constriction, and heat in the back part of the mouth, pharynx, œsophagus, and often the stomach itself. After thirst has continued, even for a short time, these parts become red and swollen, and the secretion of the mucus ceases almost entirely; that of the follicles becomes altered, thick, and tenacious; the flow of the saliva diminishes, and its viscidity sensibly increases. These phenomena are accompanied with an indefinite sense of uneasiness and general heat; the eyes become red, the spirits agitated, the motion of the blood accelerated, the respiration short and laborious, the mouth widely opened, in order to bring the external air in contact with the irritated parts, to obtain a momentary relief.

The desire of drink is increased by certain causes, such as the heat and dryness of the atmosphere, which cause a great loss of the fluid parts of the body; it is also manifest under a great number of circumstances, such as having spoken long, eaten certain aliments, or having swallowed any substance which remains in the œsophagus, &c. The pernicious habit of drinking frequently, and the desire to taste certain drinks, wine, brandy, &c., excites a sensation which strongly resembles thirst.

There are some persons who never perceive the sensation of thirst, who seem to drink merely to imitate others, but who are capable of living for a long time without thinking of it, or feeling any inconvenience from being deprived of it. There are others in whom thirst often takes place, and becomes very imperious, so as to induce them to drink from twenty to thirty pounds of fluid in twenty-four hours. We observe a great difference in this respect in individuals.

We shall not pretend to go back, with some writers, to the proximate cause of thirst, or suppose that it is the effect of the foresight of the soul, nor shall we presume to appoint to it a place, either in the nerves of the pharynx, or in the sanguineous or lymphatic vessels, because we hope that such considerations will not

hereafter find a place in scientific treatises on physiology. Thirst is an internal sensation, an instinctive sentiment; it is a result of organization, and does not admit of any explanation. The sensation of dryness and heat which accompanies it appears to be the natural expression of the condition which follows the evaporation of the watery part of the blood, or simply its excretion. Whenever we lose a large quantity of the serosity of the blood from any cause, we are tormented by thirst.

We shall not say more of the morbid phenomena which accompany and precede death, arising from a deprivation of drink; this entirely belongs to pathology.

Of Aliments and Drinks.

We give the general appellation *aliment* to every substance which is capable of nourishing the body, when it is submitted to the action of the digestive organs. According to this definition, all aliments are necessarily composed either of animal or vegetable substances; for it is only those bodies which have enjoyed life which are capable, for any length of time, of serving the purposes of nutrition in animals. But this definition of aliment is perhaps too restricted; for it may be fairly doubted whether, in the strictest sense, the name of aliment should not be applied to those substances which, though they may not be said to nourish the body, yet concur powerfully in nutrition, inasmuch as they enter into the composition of the animal organs and fluids. Such, for example, as muriate of soda, oxide of iron, silex, and especially of water, which is found in so large a quantity in the bodies of animals, and is so necessary to them. It will, therefore, be more proper to consider every substance an aliment which may assist in nutrition; preserving, however, the important distinction between those substances which are capable of performing this alone, and those which act in concert with them.*

Aliments differ from each other with respect to the immediate principles which predominate in their composition. They may be divided into nine classes, viz.: 1st. *Farinaceous* aliments: wheat, barley, oats, rice, rye, Indian corn, potatoes, sago, salop, pease, beans, and lentils. 2d. *Mucilaginous* aliments: carrots, turnips, asparagus, cabbage, lettuce, mushrooms, melons, &c. 3d. *Sweet* aliments: different kinds of sugar, figs, dried dates and raisins, apricots, &c. 4th. *Acid* aliments: oranges, gooseberries, cherries, peaches, raspberries, mulberries, pears, apples, sorrel, &c. 5th. *Oily* and *fatty* aliments: cocoa, olives, sweet almonds, fil-

* It was said by Hippocrates that there are many kinds of aliments, but that there is, at the same time, but one aliment. This proposition I have never been able clearly to understand. Did he mean that in every alimentary substance there is but one part which is nutritious? If so, this part will vary in each aliment. Or did he mean that all substances, when converted into chyle, are essentially the same? This is not the case, for the qualities of the chyle vary according to the nature of the food. Did he mean that the aliment served to renew in the blood a particular substance, which alone nourishes the body, and which is the "*quod nutrit*" of the ancients? But does any such substance exist? Can we believe that there is in all aliments a particular principle, everywhere the same, and essentially nutritive? Nothing is farther from being proved.

berts, walnuts, animal fat, oils, and butter, &c. 6th. *Caseous* aliments: different kinds of milk, cheese, &c. 7th. *Gelatinous* aliments: the tendons, aponeuroses, chorion, cellular tissue, and young animals, &c. 8th. *Albuminous* aliments: the brain, nerves, eggs, &c. 9th. *Fibrous* aliments: the flesh and blood of different animals.

Some years since I proposed to divide the aliments into those which contain little or no azote, and those which contain a large proportion of this substance.

The aliments which constitute the former are the sweet, red, and acid fruits; sugar; oils, fats, butter; mucilaginous aliments, as farinaceous articles, such as wheat, rice, potatoes, &c.

The azotic aliments are the leguminous seeds, as pease, beans, lentils, spinach, sweet and bitter almonds, nuts; the gelatinous and albuminous aliments, as cheese, &c.

This division of aliments into *azotic* and *non-azotic* is useful in its applications to regimen, especially in such diseases as gout, rheumatism, gravel, &c.

We may add to this list a great number of substances which are employed as medicines, but which, no doubt, have a nutritive effect, or, at least, some of their immediate principles; such are manna, tamarinds, vegetable extracts, sugars, animal and vegetable decoctions, commonly called *ptisans*, &c.

Among the aliments, few are used in the state in which they naturally exist. They generally require to be prepared before being submitted to the action of the digestive organs. The mode of preparation varies infinitely, according to the kind of aliments, people, climates, customs, and degree of civilization; indeed, fashion is not without its influence upon the art of preparing food.

In the hands of a skilful cook, alimentary substances change almost entirely their nature, form, consistence, odour, taste, colour, and chemical composition, &c. So entirely is the change effected, that it is often impossible to recognise the substance which constitutes the principal ingredient in some dishes. The proper object of the art of cookery is to render the aliments agreeable to the senses, and easy of digestion; but it rarely stops here. Frequently, among people in an advanced stage of civilization, the object, as well as the ambition of the artist, is to excite an impaired and fastidious appetite, or to satisfy an eccentric and capricious taste; so far from being a useful, it then becomes a most pernicious art, and leads to an infinite variety of distressing diseases, or even to premature death.

Of Drinks.—By the term drink we understand some fluid, which, when it is introduced into the digestive organs, slakes the thirst, and repairs the loss which we habitually sustain of the fluid part of our humours. We must, therefore, consider drinks as true aliments.

Drinks are divided according to their chemical composition: 1st. *Water of different kinds*, as spring, well, and river water. 2d. *Sirups, vegetable and animal infusions*, as lemon and goose-

berry sirups, whey, tea, coffee, &c. 3d. *Fermented liquors*, wine of various kinds, beer, cider, and perry. 4th. *Alcoholic liquors:* brandy, alcohol, ether, rum, &c.*

Of the Particular Acts of Digestion.

Those acts which, together, constitute digestion, are, first, prehension; second, mastication; third, insalivation; fourth, deglutition; fifth, action of the stomach; sixth, action of the small intestines; seventh, action of the large intestines; eighth, expulsion of fecal matter.

All these actions do not equally concur in the production of the chyle; the action of the stomach and of the small intestines are alone absolutely indispensable.

The digestion of solid aliments requires these eight digestive actions; that of drink is much more simple; it only requires prehension, deglutition, and the action of the stomach and small intestines. It is very rare that drinks pass to the large intestines. We shall first consider the digestion of aliments, and afterward that of drinks.

Of the Prehension of Solid Aliments.

The organs of prehension are the superior extremities and the mouth. We have already spoken of the superior extremities, and we now propose to say a few words of the different parts which constitute the mouth.

Anatomically speaking, the mouth is that oval cavity formed above by the palate and superior maxillary bone; below, by the tongue and inferior maxilla; laterally, by the cheeks; posteriorly, by the veil of the palate and pharynx; and anteriorly, by the lips. The dimensions of the mouth vary in different individuals, and are capable of being enlarged in every direction; from above below, by the depression of the tongue and separation of the jaws; transversely, by the separation of the cheeks; and from the anterior to the posterior part, by the motion of the lips and veil of the palate.

The jaws more particularly influence the form and dimensions of the mouth: the superior constitutes an essential part of the face, and only moves with the head; the inferior, on the contrary, is possessed of great mobility. The jaws are garnished with small hard bodies, called *teeth;* they are generally considered as bones, but they differ from bone in some important respects, particularly in their structure, mode of formation, uses, and from their not being altered by the contact of the air; but they resemble them in their hardness and chemical composition. There are three kinds of teeth: the incisors, which occupy the anterior part of the jaws; the molares, which occupy the posterior part; and the canine, which are situated between the incisors and molares.

* *Vide* Encyclopédie Methodique, and the Dictionnaire des Sciences Medicales, article Aliment.

We divide the teeth into two parts, the crown and the root, which differ in their structure. As the crowns of the different kind of teeth are required to perform different sorts of service, their form varies. That of the molares, or grinders, is cubical, the canine are conical, and the incisors flat, with a cutting edge. Whatever is its form, the crown is excessively hard, but it is worn away like dead matter by constant friction.

The fang, or roots, fulfil in the three kinds of teeth one common use, that of effecting a solid junction with the jaw, and of transmitting to them the powerful impressions made upon the teeth. They are received into cavities, which are called *alveolar processes*, and exactly fill them. It would appear that the walls of these cavities exert a considerable pressure upon the roots of the tooth, from the fact that they contract, and at last are filled up when the roots of the teeth are removed.

The incisors and canine teeth have but one root; the molares have generally several; but, whatever may be their number, they have always the form of a cone, the base of which corresponds to the crown, and the apex to that part which ends in the alveolar process. In some cases they present curvatures, more or less remarkable.

The edge of the alveolar process is covered with a thick, fibrous, resisting coat, which is called the *gum;* this coat is nicely fitted round the inferior part of the crown of the teeth, adheres strongly to them, and thus gives solidity to the junction of the teeth with the jaws. This coat is capable of bearing strong pressure without inconvenience. We readily see the advantages which result from this arrangement.

We must include in the number of organs that assist in the prehension of aliments the muscles which move the jaws, particularly the lower jaw; and the tongue, the motions of which have a considerable influence on the dimensions of the mouth.

Mechanism of the Prehension of the Aliments.

Nothing is more simple than the prehension of the aliments; it consists in the introduction of alimentary substances into the mouth. For this purpose the hands seize the food and divide it into small portions, capable of being contained in the mouth, and then introduce it into this cavity—perhaps by the assistance of instruments convenient for this purpose.

But, in order that it may penetrate into this cavity, it is necessary that the jaws should separate; in other words, that the mouth should open. It was long discussed whether, in opening the mouth, the inferior jaw only moved, or whether both jaws separated from each other at the same time. Without entering into this discussion, which does not merit the importance that has been attached to it, we will observe, that it is obvious that the inferior jaw moves alone when the mouth is open moderately; but when it is opened very widely, the superior jaw is raised; that is, the head is thrown slightly back on the vertebral column. But, in

every case, the inferior jaw has much the greatest extent of action, unless its depression is prevented by some physical obstacle; then the opening of the mouth depends alone upon the retraction of the head upon the vertebral column, or, what is the same thing, upon the elevation of the upper jaw.

In most cases, when the aliment is introduced into the mouth, the jaws are brought together for the purpose of retaining it, and causing it to undergo the process of mastication and deglutition. But sometimes the elevation of the lower jaw assists in the prehension of the aliments. We have one example of this in our manner of biting fruit; the incisors bury themselves in opposite directions in the alimentary substance, and act like the blades of scissors, detaching a portion of the mass. This motion is principally produced by the contraction of the elevator muscles of the inferior jaw, which represents a lever of the third kind; the power being at the insertion of the elevator muscles, the fulcrum in the temporo-maxillary articulation, and the resistance in the substance on which the teeth act.*

The volume of the substance placed between the incisor teeth influences the force with which they are pressed together. If the volume be small, the force will be much greater, for all the elevator muscles are inserted perpendicularly into the jaw, and the sum of their forces is employed to move the lever which it represents. If the volume of the body be such that it can scarcely be introduced into the mouth, even if the resistance be but little, the incisor teeth will be incapable of dividing it; because the masseter, crotophite, and internal pterygoid muscles, being inserted very obliquely on the jaw, thus lose a great part of the power with which they contract.

When the effort of the muscles of the jaws is not sufficient to detach a portion of the alimentary mass, the hands assist in the separation. On the contrary, the muscles on the posterior parts of the neck draw the head strongly backward, and, from the combination of these two efforts, a portion of the aliment is detached, and remains in the mouth. In this mode of prehension, the incisor and canine teeth are employed, but it is rare that the molares assist.

By the succession of the motions of prehension, the mouth is filled, and from the elasticity of the cheeks, and the depression of the tongue, a large quantity of aliment may be accumulated. When the mouth is full, the veil of the palate is depressed, and its inferior edge applied to the base of the tongue, so that all communication between the mouth and pharynx is interrupted.

Mastication and Mixture of the Saliva with the Aliments.

Independently of what we have said of the mouth as relates to the prehension of aliments, it is necessary to understand the uses it fulfils in masticating and mixing the food with the saliva; it is

* In carnivorous animals, where this mode of prehension is frequently employed, the three kinds of teeth participate, especially the canine.

proper to remark, that fluids, arising from different sources, abound in the mouth. The mucous membrane which lines the mouth; the numerous single, or agglomerated follicles we observe on the internal surface of the cheeks at the junction of the lips with the gums; the back part of the tongue, and the anterior surface of the veil of the palate, and uvula, pour out continually the fluid which they form on the internal surface of the mouth. It is the same of the mucous glands, which exist in great numbers in the substance of the palate and cheeks. Lastly, there are six glands, three on each side, which are called the parotids, submaxillary, and sublingual, that pour out the saliva they secrete into the mouth. The first are placed between the ear and the jaw, and have each an excretory duct, which opens on a level with the second upper molar teeth. The ducts of the maxillary glands terminate on each side of the frenum of the tongue, near which those of the sublingual glands also open.

It is probable that these fluids vary in their physical and chemical properties, according to the organ which forms them, but chemistry has not yet determined these differences by direct experiments. The mixture which we know by the common name of *saliva*, has been carefully analyzed.

Among the alimentary substances deposited in the mouth, some traverse this cavity without undergoing any change; others, on the contrary, remain for a considerable time, and experience several important modifications. The first are soft, and nearly fluid aliments, the temperature of which differs little from that of the body. The second are those which are dry, hard, or fibrous, and those the temperature of which differs, more or less, from that peculiar to the animal economy. They have both, however, this quality in common, that, in passing through the mouth, they are appreciated by the organs of taste.

There are three principal modifications which the aliments undergo in the mouth: 1st. Change of temperature; 2d. Admixture with the fluids which are poured into the mouth, and sometimes solution in these fluids; 3d. Pressure, more or less strong, and comminution, which destroys the cohesion of the parts. They are, besides, easily and frequently transported from one point of this cavity to the other. These three modes of alteration do not take place successively, but simultaneously, each favouring the other.

The change of temperature in the aliments retained in the mouth is evident; the sensations which they excite are sufficient evidence of this. If they have a very low temperature, they produce a vivid sensation of cold, which continues until they have absorbed a sufficient quantity of caloric to approach the temperature of the walls of the mouth. The reverse takes place when the temperature is more elevated than that of its walls.

Our judgment, in this instance, is formed in a manner similar to that by which we judge of the temperature of those bodies which touch the skin. We institute a comparison between the

temperature of the atmosphere and that of the body which is in contact with the mouth; so that a body preserving the same temperature will appear at one time cold, and at another warm, according to the temperature of the bodies which had been before in contact with the mouth.

The change of temperature which the food undergoes in the mouth is a mere accessory phenomenon. Its trituration, and intimate admixture with the fluids poured into this cavity, are the circumstances which merit a particular attention. As soon as the aliment is introduced into the mouth, it is pressed by the tongue against the palate and the cheeks. If the aliment has little cohesion, this simple pressure of the tongue is sufficient to spread it over the mouth; but if it be partly fluid and partly solid, it presses out the fluid part, which is swallowed, and the solid alone remains in the mouth. The tongue produces this effect readily, as the tissue is muscular, and as it is supplied with a great number of muscles which are destined to move it.

It seems surprising that a body as soft as the tongue should exert an action sufficiently strong to crush a body which presents even a slight resistance. But this is owing to the circumstance that it hardens at the same time that it contracts itself; besides, the mucous membrane which lines its superior surface is composed of a thick, dense, and fibrous coat. Such are the phenomena which are observed when the aliments offer but little resistance; but if they cohere more strongly, they are then submitted to the action of the *masticating organs.*

The essential agents of mastication are, the muscles which move the jaws, the tongue, the cheeks, and the lips; the maxillary bones and teeth can only be considered as instruments.

Though the action of both jaws may assist in mastication, it is almost entirely performed by the lower jaw. This bone is capable of being elevated and pressed strongly against the upper jaw, and moved forward, backward, and sideways. These different motions are produced by numerous muscles which are attached to the bone; but the jaws could not fulfil the function to which they are destined if they were not garnished with teeth, the physical qualities of which render them particularly adapted to this purpose.

A few remarks on these bodies are necessary to clearly understand what follows. The use of the molar teeth is to grind the food; they are twenty in number, ten in each jaw, five on the right and five on the left side. The form of their crown is that of an irregular cube; the corresponding surfaces are composed of pyramidal eminences, varying in number in the different teeth. In the anterior molares they are small, but large in the posterior. These asperities and cavities are so arranged that those of the upper correspond with those of the lower jaw.

At the lower and middle part of the crown there exists a cavity, filled with an organ which, in the early periods of life, secretes the tooth. The root is hollowed out into a canal, which is

occupied by an artery, vein, and filament of a nerve. The substance which forms the teeth is of an excessive hardness, particularly its external coat or *enamel*. Being destined to crush bodies the resistance of which is sometimes very great, it is necessary that they should present a proportional degree of hardness; more especially as they are destined to exercise this office during life, and it is, therefore, necessary that they should be worn away very slowly. On this account, extreme density was indispensable, for any body, however hard it may be, cannot fail to be worn down by continued friction.

The substance which forms the body and root of the teeth is homogeneous in all its parts; the enamel, on the contrary, which composes the crown of the tooth, presents fibres which are arranged perpendicularly to the surface of the bony part of the tooth, and strongly adhering to it. The phosphate and carbonate of lime constitute nearly the whole of the teeth in man. In 100 parts, 99.5 are of this salt, the remainder being animal matter.* In the enamel there is scarcely any animal matter, and it is to this circumstance that we must attribute its whiteness and excessive hardness.

We have already shown how solid the articulation of the teeth with the jaw is; the molar teeth, in consequence of the office which they perform, possess this firmness in the highest degree; their roots are also more numerous, though not so large as in those which have but one. Finally, whether single or double, their form is conical, and they are received into cavities to which they are adapted, which are called alveolar processes; each tooth represents a wedge buried in the jaws. The teeth in each jaw, together, form what are called the dental arches.

The form of the arch is the half of a parabola, the inferior being somewhat larger than the superior. The inferior edge of the upper is a little inclined outward, but that of the lower inward. These edges present, at that part formed by the molar teeth, a groove, bounded by two ranges of eminences. When the jaws are brought together, the incisors and canine teeth of the lower jaw are placed behind the superior. The external projecting edge of the inferior dental arch enters the groove of the superior arch. When the edges of the incisors are brought in contact, there is an interval left between the molar teeth. To add firmness to the junction of the teeth with the jaws, nature has so arranged them that the sides of nearly all are in contact, which in this way present a particular *facette*. The result of this disposition is, that, when one of the teeth is exposed to a considerable pressure, it is supported by all the teeth which compose the arch.

These facts being known, it is easy to understand the explanation of the mechanism of mastication.

* I have found, from experiment, that the proportion of animal matter is very great in herbivorous animals, and still greater in carnivorous. The proportion of carbonate of lime is greater in herbivorous animals than it is in those which are carnivorous, or in man.

Mechanism of Mastication.

When mastication begins, the lower jaw is depressed, an effect which is produced by the relaxation of the elevator and the contraction of the depressor muscles. The food is introduced within the dental arches by the tongue or some other means. The inferior jaw is then raised by the masseter, internal pterygoid, and temporal muscles, the contraction of which is proportioned to the resistance of the aliments. The food, being pressed between two unequal surfaces, the asperities of which grind against each other, is divided into small portions, the number of which is proportioned to the facility with which they are acted upon.

But a single motion of this kind only affects one part of the aliments contained in the mouth, and it is required that all should undergo this operation. This is effected by a succession of motions of the inferior jaw, by the contraction of the muscles of the cheek, tongue, and lips, which carry, successively and promptly, the aliment between the teeth when the jaws are separated, so that it may be crushed when they are brought together. When the food is soft, two or three movements of the jaws are sufficient to divide all that is contained in the mouth, each of the three different kinds of teeth performing their part; but the mastication must be prolonged when the substances are tough, fibrous, or coriaceous: we then use only the molar teeth, and generally those of one side at a time, as if to enable the other to remain at rest. In using the molar teeth, the resisting arm of the lever, which is represented by the lower jaw, is shortened, and thus rendered more favourable to the power which moves it.

The teeth are submitted to a very considerable power during mastication, which would inevitably loosen, if not displace them, if they were not very strongly articulated with the jaws. Each root acts like a wedge, and transmits to the alveolar processes the force with which it is pressed.

The advantage arising from the conical form of the root is by no means doubtful. In consequence of this form, the force which presses upon the tooth, and tends to thrust it into the jaw, is divided; one part has a tendency to separate the walls of the alveolar process, the other to thrust it inward; thus the force, instead of being transmitted to the extremity of the root, which must have taken place if it had been cylindrical, is applied to the whole alveolar surface. The molar teeth, which have to endure considerable force, have several roots, or, at least, one very large root. The incisor and canine teeth, which have but one root, and that not very large, are never compelled to endure a very strong pressure.

If the gums had not presented a smooth surface and a dense tissue, placed as they are about the necks of the teeth and filling up their intervals, they would have been subject every instant to be torn; for, in the mastication of hard substances of an irregular form, they are every moment exposed to be pressed strongly by

the edges and angles of these substances. This inconvenience is actually felt whenever their tissue is softened, as in scorbutic affections.

During mastication, the mouth is closed posteriorly by the veil of the palate, the anterior face of which is applied against the base of the tongue; anteriorly, the food is retained by the teeth and lips.

Insalivation of the Aliments.

When we have an appetite, the sight of aliments determines a considerable afflux of saliva to the mouth. In some persons this is sufficiently strong for the saliva to be projected to the distance of several feet. I have actually seen an instance of this. The presence of aliment in the mouth excites this secretion. While the aliments are bruised and triturated by the organs of mastication, they imbibe these fluids, which are copiously poured into the mouth at this time, especially the saliva. It is easy to conceive that the division of the aliment, and the frequent displacement which it undergoes during mastication, will singularly favour its admixture with the mucus and salivary fluids. In their turn, these fluids facilitate mastication by softening the aliment. The greater number of alimentary substances, when submitted to the action of the mouth, become dissolved or suspended, wholly or in part, in the saliva, and at this moment become proper to be introduced into the stomach, and are soon swallowed. In consequence of its viscidity, the saliva absorbs the air which is combined with it in the various movements which are required in mastication, but the quantity of air absorbed in this way is inconsiderable, and has been generally much exaggerated.

We cannot say positively what purpose is answered by the trituration of the food, and its admixture with the saliva; whether it be a simple division, which renders it more convenient for the alteration which it is destined to undergo in the stomach, or whether it experiences in the mouth the first degree of animalization. We will, however, remark, that the taste and odour of the aliment are altered during mastication, and that, when mastication is prolonged, it in general renders digestion more prompt and easy. On the contrary, that persons who do not chew their aliments have frequently, from this circumstance alone, slow and imperfect digestion. We know when mastication and the admixture of the saliva are carried to a sufficient extent by the degree of resistance of the aliments, and the taste which they excite. Besides, the walls of the mouth, and especially the tongue, being endowed with the sense of touch, can appreciate the physical changes which take place in the aliments. Some authors have attributed this to the uvula. I much doubt, however, the correctness of this opinion. The uvula, from its situation, has no connexion with the aliment during its mastication. I have often noticed persons who had lost the uvula, either by a venereal ulcer, or by excision, and I have never found that their mastication or deglutition was the least deranged.

Of the Deglutition of Aliments.

We understand by deglutition the passage of a solid, liquid, or gaseous substance from the mouth into the stomach. The deglutition of solid aliments will first occupy our attention.

Though apparently simple, deglutition is by far the most complicated of all the muscular actions which assist in digestion. It is produced by the contraction of a great number of muscles, and requires the concurrence of many important organs. All the muscles of the tongue, those of the veil of the palate, the pharynx, larynx, and the muscular coat of the œsophagus, assist in deglutition. We ought to have an exact and detailed knowledge, if we wish to form a just idea of this act. The nature of this work will not admit of our explaining all the anatomical details. We shall limit ourselves to a few remarks upon the veil of the palate, the pharynx, and œsophagus.

The *veil of the palate* is a sort of valve, attached to the posterior edge of the arch of the palate; its form is four-sided. The inferior or loose edge is prolonged into a point, which is called the *uvula.* Like other valves of the intestinal canal, the veil of the palate is essentially formed by a duplicature of the digestive mucous membrane; there enters into its composition many mucous follicles, especially about the uvula. It is moved by eight muscles, viz., the two *internal pterygoid,* which elevate it; the two *external pterygoid,* which stretch it transversely; the two *pharyngo-staphylini* and the two *glosso-staphylini,* which draw it down. These last four extend to the lower part of the throat, and are there covered by the mucous membrane, and form the *pillars of the veil of the palate,* between which are situated the *tonsils,* a collection of mucous follicles. The opening comprehended between the base of the tongue below, the veil of the palate above, and the lateral pillars, is sometimes called the *isthmus of the throat.*

By means of this muscular apparatus, the veil of the palate undergoes many changes of position. Its most common situation is vertical, one of its faces being anterior and the other posterior. In certain circumstances it becomes horizontal; it then has a superior and an inferior face, and its loose edge corresponds to the concavity of the pharynx. This last position is determined by the contraction of the elevator muscles.

Bichat asserts that the elevation of the veil of the palate may be carried to such an extent as to be applied to the opening of the posterior nares; this motion seems to be impracticable; there is no muscle arranged in such a manner as to produce it, and the disposition of the pillars evidently oppose it. The depression of the veil is executed by the contraction of the muscles which form the pillars. We have already remarked that these motions are not submissive to the will in a great number of individuals.

The *pharynx* is a sort of vestibule, into which the nasal fossæ, the Eustachian tubes, the mouth, the larynx, and œsophagus open.

It fulfils important functions in the production of the voice, in respiration, in hearing, and digestion. The pharynx extends from the *basilary process* of the occipital bone, to which it is attached above, to a level with the middle part of the neck below. Its transverse dimensions are limited by the os-hyoides, the larynx, and the aponeurosis of the *pterygo-maxillaris*, to which it is attached. The mucous membrane, which covers it interiorly, is distinguished by the development of its veins, which form here a very remarkable network. Near this membrane is the muscular coat, the circular fibres of which form the three constrictor muscles of the pharynx, and the longitudinal fibres of which are represented by the *stylo-pharyngeus* and the *pharyngo-staphylini* muscles. The contractions which these muscles execute are not, in general, submissive to the will.

The *œsophagus* is immediately attached to the pharynx, and is prolonged to the stomach, where it terminates. Its form is cylindrical; it is united to the surrounding parts by a loose and extensible cellular tissue, which adapts itself to its dilatation and other motions. To penetrate into the abdomen, the œsophagus passes between the pillars of the diaphragm, with which it is intimately united.

The mucous membrane of the œsophagus is white, thin, and delicate; it forms longitudinal folds, which facilitate its dilatation. Above, it is lost in the pharynx. Dr. Rullier has lately called the attention of anatomists to several indentations formed in its lower part, which terminates by a sort of fringed edge, hanging loose into the cavity of the stomach.*

We meet in its substance a great number of mucous follicles, and we distinguish on its surface the orifices of many excretory ducts of mucous glands. The muscular coat of the œsophagus is thick, and its tissue more dense than the pharynx; its longitudinal fibres are more external, and less numerous; the circular are placed on the interior, and are very numerous.

Near the pectoral and inferior part of the œsophagus the eighth pair of nerves form a plexus, which embraces the canal, and sends many filaments to it. The contraction of the œsophagus is made without any participation of the will.

Mechanism of Deglutition.

For the better understanding of the subject, we shall divide deglutition into three stages. In the first, the aliments pass from the mouth into the pharynx; in the second, they pass over the openings of the glottis and nasal fossæ, and arrive at the œsophagus; in the third, they pass through this canal into the stomach.

Let us suppose a common case: that, for example, we have swallowed several times a part of the aliment in the mouth, as its mastication has been completed.

* There is between the mucous membrane of the œsophagus and the stomach in man as striking a difference as that which exists between this same membrane in the cardiac and pyloric half, in the stomach of a horse.

As soon as there is a certain quantity of food masticated, it is placed on the superior surface of the tongue by the action of mastication, without any necessity, as some have supposed, that the apex of this organ should pass into all the angles of the mouth to collect it together. Mastication then ceases; the tongue is elevated, and applied to the arch of the palate, successively, from the apex to its base. The portion of aliment placed on its superior surface having no other way to escape from the pressure to which it is exposed, is directed towards the pharynx, where it meets with the veil of the palate applied over the base of the tongue, which it causes to be elevated, the veil becoming horizontal. The tongue continuing to press the aliments, they would be carried towards the nasal fossæ, if this was not prevented by the tension which the veil receives from the external *peristaphilini* muscles, and especially by the contraction of its pillars. It becomes thus capable of resisting the action of the tongue, and of contributing to direct the aliments towards the pharynx.

The muscles which more particularly act in applying the tongue to the arch of the palate and to the veil of the palate are the proper muscles of this organ, aided by the *mylo-hyoideus.* This terminates the first stage of deglutition. The motions are all voluntary, with the exception of those of the veil of the palate. The phenomena take place in succession, and with little promptitude; they are few in number, and easy to comprehend.

The same remarks will not apply to the *second stage.* There, the phenomena are simultaneous, multiplied and produced with such rapidity, that Boerhaave considered them a sort of convulsion. The space which the morsel has to pass over in the second stage is very short, being only from the middle to the lower part of the pharynx. But it must be prevented from entering either the glottis or the nasal fossæ, where it would prove injurious. Besides, its passage must be so rapid as not to interrupt, but for a moment, the free communication between the external air and the larynx. We shall now see how nature accomplishes this important purpose.

The morsel of food no sooner reaches the pharynx than every part of it is thrown into action. It at first contracts itself, embracing and holding firm the morsel of food; the veil of the palate, drawn down by its pillars, acts at the same time. On the other side, and almost at the same instant, the base of the tongue, the os-hyoides, and the larynx are elevated, and carried forward, so as to meet the morsel and facilitate its passage over the opening of the glottis. At the same time that the os-hyoides and larynx elevate themselves, they approach each other; that is, the superior edge of the thyroid cartilage is pressed behind the body of the os-hyoides, the gland of the epiglottis is pushed backward, the epiglottis itself depressed, and inclines downward and backward, so as to protect the entrance of the larynx. The cricoid cartilage executes a rotation upon the inferior horns of the thy-

roid, from which it results that the entrance of the larynx becomes oblique from above downward, and from before backward. The morsel glides over its surface, and continuing to be pressed by the contraction of the pharynx and the veil of the palate, it arrives at the œsophagus.

It will not require much consideration to understand the position which the epiglottis, in this case, assumes, if it be considered as the only obstacle which prevents the entrance of the aliments into the larynx at the moment of deglutition. But I have shown, by a series of experiments, that this cause can only be considered as accessory. We can, in fact, entirely remove the epiglottis from an animal, without deglutition being impeded. Let us inquire, then, what is the reason why no part of the food is introduced into the larynx at the moment of swallowing. At the instant that the larynx is elevated, and forced behind the os-hyoides, the glottis is closed with great exactness. This motion is effected by the same muscles which contract the glottis in the production of the voice. So that, if we divide the laryngeal and recurrent nerves of an animal, leaving the epiglottis untouched, we render deglutition extremely difficult, because we have taken away the principal cause which prevents the introduction of the aliment into the glottis. Immediately after the morsel has passed the glottis, the larynx descends, the epiglottis is raised, and the glottis again opened to give passage to the air.*

From this explanation, it is easy to comprehend how the aliments, when swallowed, arrive at the œsophagus without penetrating into any of those openings which are so numerous in the pharynx. The veil of the palate, at the moment when the pharynx contracts itself, protects the posterior nares, and the orifices of the Eustachian tubes; the epiglottis, and especially the motion by which the glottis is closed, protects the larynx.

We have thus finished the description of the second stage of deglutition, and traced the morsel of food, as it has passed through the mouth and pharynx, until it has arrived at the upper part of the œsophagus. All the phenomena exhibited in the second stage take place simultaneously, and with great rapidity; they are not controlled by the will, and differ, therefore, in many respects, from the phenomena observed in the first stage.

The third stage of deglutition has been examined with less care; in consequence, probably, of the situation of the œsophagus, which it is not easy to observe, except at its cervical portion. The phenomena are not complicated. By its contractions, the pharynx pushes the morsel into the œsophagus with sufficient force to dilate the superior part of this organ. Its superior circular fibres, excited by the presence of the morsel, contract and thrust the ali-

* I have known two instances of individuals in whom the epiglottis was entirely wanting, but in whom deglutiton was performed without any difficulty. If, in a laryngeal phthisis, with destruction of the epiglottis, deglutition is imperfect and laborious, it arises from the arytœnoid cartilages being carious, and the edges of the glottis ulcerated, so that they become incapable of closing exactly the opening of the glottis.

ment towards the stomach, causing the distention of those parts which are below; these, again, contract in their turn, and this action is repeated until the morsel arrives at the stomach. In the two superior thirds of the œsophagus, the relaxation of the circular fibres immediately follows the contraction, by which the morsel is displaced. It is not the same in the inferior third, which remains contracted for some time after the introduction of the food into the stomach.

We should be mistaken if we supposed that the passage of the morsel through the œsophagus was very rapid. I have been astonished, in my experiments, to find how slow its progress is; often two or three minutes elapse before it reaches the stomach; at other times it stops and remains for a considerable time on each spot. I have seen it, in some instances, rise from the inferior extremity of the œsophagus towards the upper part, and afterward descend. When any obstacle prevents its entrance into the stomach, this motion is repeated a great number of times before the aliment is rejected by the mouth. This explains the sensation we often perceive of the aliment remaining in the œsophagus, which induces us to drink in order to make it descend into the stomach.

When the morsel is very large, its progress is still more slow and difficult. It is accompanied by a vivid sense of pain, produced by the distention of the nervous filaments, which surround the pectoral portion of the canal. Sometimes the morsel is arrested entirely, and occasions the most serious accidents.

Professor Halle observed, in a woman affected by a disease which enabled him to see the interior of the stomach, that the arrival of a portion of aliment in this viscus was immediately followed by the formation of a sort of *hood* at the cardiac orifice. This *hood* was formed by the displacement of the mucous membrane of the œsophagus, which was thrust into the stomach by the contraction of the circular fibres of the canal.

The whole extent that the morsel has to pass over, during the three stages of deglutition, is copiously lubricated by mucus. The morsel, pressing out the contents of the follicles which it meets in its passage, glides easily along the mucous membrane. We may remark, that at those points where the morsel passes most rapidly, and is pressed with the most force, the mucous secretory organs are the most numerous. For example, in the narrow space where the second stage of deglutition takes place, there are found the tonsils, the fungous papillæ at the base of the tongue, the follicles of the veil of the palate and of the uvula, those of the epiglottis, and the arytœnoid glands; in this respect, the saliva and mucus fulfil uses analogous to those of the synovia. The mechanism by which we swallow the other morsels does not differ from what has been above related.

Nothing can be easier than to execute deglutition, while nearly all the acts which compose it are beyond the influence of the

will, and under the dominion of instinct. We are incapable of altering a single motion of nutrition. If the substance contained in the mouth is not sufficiently masticated; if it does not possess the form, consistence, and dimensions of the alimentary morsel; and if the motions of mastication, which immediately precede deglutition, have not been made, with all our exertions we shall be unable to swallow it. How common a thing is it to see persons incapable of swallowing a pill, and who are obliged to have recourse to various means to introduce it into the stomach!

In order to form an idea of the part which the will takes in deglutition, we may make the following experiment upon ourselves. Let any one endeavour to execute five or six motions of deglutition, in which he swallows the saliva. The first, and even the second time, this will be easily accomplished; but the third time it will be more difficult, because there will remain but little saliva in the mouth; the fourth it will be impossible to execute until a certain period will elapse, when new saliva will be thrown into the mouth; but the fifth and sixth will be impracticable, because there will not be any saliva to swallow. Every one may recollect how difficult deglutition is whenever the mouth and pharynx are dry.

Of the Abdomen.

The digestive actions which remain to be examined by us take place in the cavity of the abdomen, the disposition of which deserves to be studied with attention.

The abdomen is the largest of the cavities of the body, and admits of the greatest augmentation of its capacity. It contains a great number of organs, which are destined to perform certain important functions, as generation, digestion, secretion of urine, &c. Its walls are chiefly muscular, and have a very marked action on the organs they contain. The form of the abdominal cavity is irregularly ovoid. In consequence of its large dimensions, and in order to give precision to language, it is divided into several regions, which have each received a particular name.

To understand this division, which is purely artificial, it will be necessary to suppose two horizontal planes, one of which divides the abdomen on a level with the crests of the ilii, and the other on a level with the inferior false ribs. The part of the abdomen placed beneath the first plane is called the *hypogastric* region; that which is found above the second, the *epigastric;* and that comprehended between the two planes, the *umbilical.*

Suppose, now, that two vertical planes, passing from the side of the head, should fall upon the anterior and inferior spines of the ilium, dividing the abdomen from before backward, it is plain that each of the three abdominal regions of which we have been speaking will be subdivided into three compartments of dimensions nearly equal. It will be found convenient to designate these subdivisions by the following names. The middle may be called the *epigastrium*, and the two sides the *hypochondriac re-*

gions; the umbilical region, called right, left, and middle; lastly, we may give the name of *hypogastrium* to the middle division of the hypogastric region, while we call the sides the iliac regions.

By means of these artificial divisions we may fix, with exactness, the position and respective relations of the organs contained in the abdomen, which will be found extremely convenient both in physiology and medicine.

Above, the abdomen is separated from the chest by the diaphragm, a muscle disposed in the form of an arch, and the contraction of which has a great influence on the position, and even upon the action, of the organs contained in the abdomen. The circumference of the diaphragm is attached to the edge of the false ribs and the vertebral column. In a state of relaxation, its centre is raised to a level with the sixth and seventh true rib; but at the instant that this muscle contracts strongly, it occasions a considerable diminution of the abdominal cavity, compresses all the organs which it contains, and distends the soft parts which form its walls.

The inferior part of the abdomen is formed by the pelvis, the firm bones of which support the weight of a part of the viscera, and allow a place of insertion for the muscles, but do not assist in producing variations in the capacity of the abdomen, except under circumstances extremely rare. It is proper to remark, that the space comprehended between the *coccyx*, the *tuberosities of the ischia*, and the arch of the pubis, is filled with soft parts, and particularly by the *ischio coccygeus*, and the *elevator* and *external sphinctor ani muscles.*

Anteriorly and laterally the walls of the abdomen are formed by the abdominal muscles. These muscles, as we have already seen, concur powerfully in the different attitudes and motions of the trunk, and have also effect in digestion and generation, &c. Among these muscles, those which are large and situated on the sides are destined to contract the abdomen, and to compress the viscera which are contained in it.

The long muscles, situated anteriorly, are most generally the antagonists of the first. They resist their action, and may, under certain circumstances, augment the dimensions of the abdomen, and diminish the pressure which the viscera support.

From the ensiform cartilage to the pubis there exists a fibrous line, formed by the crossing of the fibres of the aponeuroses of the abdominal muscles; this is called by anatomists the *linea alba.* Its uses will hereafter be explained.

Most generally, the muscles which compose the abdominal walls are directed by the will; but there are also circumstances where they instinctively contract, when they display a much greater degree of energy than in ordinary cases.

Action of the Stomach upon the Aliments.

Thus far we have only seen the physical actions of the digestive organs upon the aliments; we shall now examine those ac-

tions which are almost entirely chemical. In the stomach the aliments are transformed into a substance peculiar to animals, which is called *chyme*. But, before treating of the phenomena which its formation presents, we will say a few words of the stomach itself.

Of the Stomach.

The stomach is placed between the œsophagus and the duodenum; it occupies, in the abdomen, the epigastric and a part of the left hypochondriac region; its form, though variable, is, in general, that of a *conoid*, curved upon itself. The left half of the stomach is always much larger than the right; and as these two halves take a different part in the formation of the chyme, I have thought it useful to name the one the *splenic half*, because it is in contact with the spleen, and the other the *pyloric half*, because it corresponds to the pylorus. These two parts are frequently separated from each other by a particular contraction.

The stomach being destined to allow the aliments to accumulate in its cavity, it is evident that its dimensions, situation in the abdomen, and relations with the neighbouring organs, must undergo great variations. This organ has two orifices: the one corresponds to the œsophagus, which is called the cardiac orifice; the other communicates with the small intestines, and is called the intestinal, or pyloric orifice.

The three membranes, or tunics, which compose the stomach present dispositions the most favourable to variations in the volume of the organ. The exterior, or peritoneal coat, is formed of two laminæ, slightly adhering to the viscus. These are prolonged, without uniting, for a considerable distance from its edge, and thus form what is called the *epiploon*, or *omentum*, the extent of which is, therefore, in an inverse ratio to the volume of the stomach.

The mucous membrane of the stomach is of a reddish white, and marbled; it presents a great number of irregular folds, situated particularly on the inferior and superior edges of the organ; they are also seen on its splenic extremity. They are the more numerous and remarkable when the stomach is contracted upon itself.

There is no part of the digestive mucous membrane which presents so many and such fine villosities as the stomach. It is constantly covered, on its splenic half, by a mucus adhering to its surface. We also meet with many follicles in its substance, but it is important to observe that they are very abundant in the pyloric portion. We see a certain number in the neighbourhood of the cardiac orifice; they are rare in the other parts of the membrane.

At the pylorus the mucous membrane forms a circular fold, called the *valve of the pylorus*. Between its two laminæ is found a dense, fibrous tissue, designated by some authors by the name of the *pyloric muscle*.

With respect to the muscular coat of the stomach, it is very thin; its circular and longitudinal fibres are separated from each other, especially on the splenic part; this separation increases or diminishes with the volume of the stomach.

There are few organs which receive so much blood as the stomach; four arteries, of which three are large, are sent exclusively to it. Its nerves are not less numerous; they are composed of the eighth pair, and of a great number of filaments coming from the *solar plexus* of the *great sympathetic.*

Accumulation of Aliments in the Stomach.

Before explaining the changes which the aliments undergo in the stomach, it is necessary to be acquainted with the phenomena of their accumulation in this viscus, and the local and general effects which result from them.

The first morsels which are swallowed are easily lodged in the stomach. This organ is but little compressed by the surrounding viscera; its walls easily separate, and yield to the force with which the morsels are thrust into the organ. But, as new portions of aliment arrive, its distension becomes more difficult, for it must be accompanied with a pressure of the other viscera, and an extension of the abdominal walls. It is especially towards the cardiac extremity and the middle part that the accumulation takes place; the pyloric portion is not so readily distended.

At the same time that the stomach is distended, its form, relations, and even its position become modified. Instead of being flattened, and occupying only the epigastrium and left hypochondriac region, it assumes a rounded form; its large *cul de sac* is buried in this hypochondrium, and fills it up almost entirely. The large curvature descends towards the umbilicus, or navel, especially on the left side. The pylorus, however, fixed by a fold of the peritoneum, preserves its positions and relations with the surrounding parts.

In consequence of the resistance offered by the vertebral column posteriorly, the stomach is not dilated in this direction. The result, therefore, is, that the viscus is entirely carried forward; and, as the pylorus and œsophagus cannot be displaced in this direction, it undergoes a rotary motion, by which its large curvature is directed forward, its posterior face inclined below, and its superior upward.

In undergoing these changes of relation and position, however, it preserves a conoid figure, curved upon itself, which is peculiar to it. This arises from the manner in which the three tunics contribute to its dilatation. The two laminæ of the serous membrane are separated, and give way to the stomach; the muscular undergoes a true distension; its fibres elongate, but so as to preserve the peculiar form of the stomach; lastly, the mucous membrane yields, especially in those parts where its folds are most numerous, which, it will be remembered, are the cardiac extremity, and along the large curvature.

The dilatation of the stomach alone produces important changes. The whole extent of the cavity is augmented, the belly becomes prominent, the abdominal viscera compressed with more force, and often a desire of avoiding the fæces and urine is felt. The diaphragm is crowded into the chest, and is depressed with difficulty; the action of respiration becomes less easy, and those phenomena which depend upon it, as speaking and singing, become modified, &c. In some cases, the dilatation of the stomach may be carried to such an extent that the abdominal walls become painfully distended, and the respiration really difficult.

For the production of such effects, it is evident that the contraction of the œsophagus, which thrusts the aliment into the stomach, must be very energetic. We have already spoken of the considerable thickness of the muscular coat of this canal, and the great number of nerves distributed to it. There is nothing but this peculiar structure which can explain the force with which the aliments distend the stomach. To satisfy ourselves of this, we have only to introduce a finger into the œsophagus of an animal at its cardiac orifice, and we shall be surprised at the force with which it contracts. But if the aliments exert so marked an influence on the walls of the stomach and abdomen, they must themselves undergo a proportionate reaction, and tend to escape from the two openings of the stomach. It is generally said that this effect does not take place in consequence of the firmness with which the cardia and pylorus close themselves; but this phenomenon has never been directly investigated.

The following experiments on this point were made by myself. The alternate motion of the œsophagus prevents the return of the aliments into its cavity. The more the stomach is distended, the more intense and prolonged is this contraction, and the shorter the duration of the relaxation. The contraction, for the most part, takes place at the moment of inspiration, when the stomach is very strongly compressed. The relaxation happens frequently at the moment of expiration.

We can form an idea of this mechanism by laying bare the stomach of a dog, and endeavouring to press back the aliments into the œsophagus with both hands. We shall find it almost impossible to do this, whatever be the force we employ, if we make the attempt at the time the œsophagus is contracted; but this will be easily done if we compress the viscus at the moment of relaxation.

The resistance which the pylorus opposes to the aliments is of a different kind. In living animals, whether the stomach be full or empty, this opening is closed by the constant contraction of this fibrous ring, and the fibres of which it is composed. We see frequently in the stomach another obstruction, one or two inches distant, which appears destined to prevent the aliments from arriving at the pylorus.* We may distinguish, also, irregular and

* This structure is very remarkable in carnivorous animals, and herbivorous animals with one stomach.

peristaltic contractions, which begin in the duodenum, and are prolonged in the pyloric portion of the stomach, the effect of which is to thrust the aliments towards the cardiac portion. Besides, when the pylorus is not naturally and firmly closed, the aliment has but little disposition to introduce itself into this opening, as its natural tendency must be to pass in the direction where the pressure is least; and this will, of course, be as great in the small intestines as in the stomach, inasmuch as the pressure is nearly equal over the whole cavity of the abdomen.

In the number of phenomena produced by the presence of aliments in the stomach, there are several the existence of which, though generally admitted, have never been sufficiently demonstrated. Such, for example, as the diminution of volume in the spleen, and sanguineous vessels of the liver and omentum; the motion of the stomach, called by authors the *peristole*, which presides over the reception of aliments, distributing them equally, and exerting upon them a gentle pressure; so that its dilatation, so far from being passive, would be essentially active. I have frequently laid open the abdomen of animals when the stomach was filled with aliment, and have often examined the bodies of criminals shortly after death, but I have never seen anything to justify these assertions.

The accumulation of aliments in the stomach is accompanied with several sensations, which it is proper to notice. The first is the agreeable sensation which we receive in gratifying this natural want. The sensation of hunger is gradually appeased; the general weakness which accompanies it is replaced by a new sensation of activity and vigour. But if more food be introduced, a sense of fulness and satiety is induced, which shows that the stomach is full. If, notwithstanding this instinctive warning, we persist in eating more, disgust and nausea supervene, and are shortly followed by vomiting.

These different sensations do not entirely depend upon the volume of the food; other things being equal, nutritious aliment induces soonest a sense of satiety. A substance which is but little nutritious calms but imperfectly the sense of hunger, even when it is taken in considerable quantity. The mucous membrane, therefore, is endued with a considerable degree of sensibility, inasmuch as it distinguishes the nature of the substances brought in contact with it. This quality manifests itself in a very remarkable manner when any poisonous substance is brought in contact with it, when it produces intense pain; we know, also, that it is sensible to the temperature of aliments.

From the redness of the mucous membrane, the quantity of fluid which it secretes, and the size of the vessels which are ramified upon it, we cannot doubt that the presence of aliments in the stomach produces an excitement useful in the process of chymification. This excitation of the stomach has a powerful influence upon the general state of the functions, as will be shown hereafter.

The aliments remain in the stomach a considerable length of time generally; for several hours, during which they are formed into chyme. We will now examine the phenomena which attend this transformation, which has been heretofore but imperfectly investigated.

Alteration of the Aliments in the Stomach.

The aliment remains in the stomach, generally, about one hour before it undergoes any perceptible change but what arises from its admixture with the fluids which are continually poured into this organ. During this time the stomach remains uniformly distended; at last, the pyloric portion contracts itself through its whole extent, especially towards the point nearest to the cardiac portion, during which the aliments are forced back. From this time, we find in the pyloric portion nothing but chyme, mixed with a very small portion of aliment unchanged.

The highest authorities have agreed in considering chyme as a homogeneous, pultaceous, grayish substance, of a sweetish, insipid taste, slightly acid, which preserves some of the properties of aliments. But this description is far from being perfect. Indeed, the circumstances under which the chyme assumes these characters, and the sort of aliments which had been used, are not mentioned, though it is evidently important that they should be known. I thought that some new experiments on this subject would be useful. I shall not record here all the details of those which I have made, but only the most important results. There are as many kinds of chyme as there are sorts of aliments, if we may judge from their colour, consistence, aspect, &c. This any person may easily satisfy himself of, by causing dogs to eat different sorts of simple alimentary substances, and killing them during the process of digestion. I have also repeatedly confirmed this observation in man, upon criminals, and persons dying suddenly from accidents.

In general, animal substances are more easily and completely altered than vegetable. It happens, frequently, that these last traverse the whole of the canal without changing their characters. I have often seen in the rectum and small intestines greens, spinach, &c., which had been added to the soup, preserving all their properties, their colour only being altered by the bile. The chyme is particularly formed in the pyloric portion. It would appear that the aliments are introduced by degrees, and that, during their stay, they undergo a transformation. I have, however, often seen chymous matter on the surface of the mass of aliments which fill the cardiac portion; but generally the aliments in this part of the stomach preserve their peculiar properties.

It is difficult to say why the pyloric portion is better suited to the formation of the chyme than the rest of the stomach. Perhaps the great number of follicles observed there induce some modification in the quantity or nature of the fluid secreted. The transformation of alimentary substances into chyme takes place,

generally, from the surface towards the centre. There is formed on the surface of the portions of aliment swallowed a soft coat, easily detached. They appear to be acted upon by an agent, which completely dissolves them. A morsel of the white of an egg, boiled hard, for example, is acted upon as if it had been dipped in vinegar, or a solution of potash. Whatever may be the substance employed, the chyme has always a sour taste and smell, and turns the purple juice of vegetables red. A very small quantity of gas is found in the stomach during the formation of chyme; often it does not exist at all; sometimes it is formed like a small bubble at the superior part of the cardiac portion. I have been able, by great care, in one instance, in the body of a criminal recently executed, to collect a sufficient quantity of this gas for analysis. M. Chevreul found it composed of

Oxygen	11.00
Carbonic acid	14.00
Pure hydrogen	3.55
Azote	71.45
Total	100.00

It is rare that we meet with gas in the stomach of a dog.

I cannot believe, with Professor Chaussier, that with each act of deglutition we swallow a bubble of air, which is thrust into the stomach with the alimentary morsel. If this were the case, we ought to find in this organ a considerable quantity of air after eating, which is not the fact.

A large quantity of chyme does not accumulate in the pyloric portion of the stomach; the most I have seen was hardly equivalent in volume to two or three ounces of water. It would appear that the contraction of the stomach has an influence upon the formation of the chyme, from the following observations made by myself. After having remained for some time immovable, the extremity of the duodenum contracts itself, which is followed by a similar action in the pyloric portion of the stomach. This motion forces the chyme towards the cardiac portion, but afterward the contraction is made in an opposite direction; that is, after being distended, and having permitted the chyme to return anew into its cavity, the pyloric portion contracts itself from the left towards the right side, directing the chyme towards the duodenum, which overcomes the action of the pylorus, and penetrates into the intestine. This phenomenon is repeated for a certain number of times, after which it is stopped, and the same process is renewed. When the stomach contains much aliment, this motion is limited to that part of the organ nearest to the pylorus; but, as it becomes emptied, the motion extends itself more and more, and at last becomes manifest in the cardiac portion, when the stomach is nearly empty. In general, it becomes more distinctly marked towards the end of chymification. Some persons have a distinct consciousness of it at the time.

The pylorus has been supposed by some to act a very impor-

tant part in the passage of the chyme from the stomach to the intestine. It judges, according to some, of the degree of chymification of the aliments; it opens and allows those parts to pass which possess the requisite qualities, but closes itself against those which do not present them. We know, however, from daily experience, that undigested and indigestible substances, as the stones of fruit, and other substances incapable of being converted into chyme, at last pass easily through it. These opinions, which are in some degree consecrated by the meaning of the term pylorus (a doorkeeper), may serve to amuse us, but they are, after all, mere hypotheses.*

All alimentary substances are not transformed into chyme with an equal degree of facility. In general, fatty substances, tendons, cartilages, concrete albumen, and mucilaginous and sweet vegetables, resist longer the action of the stomach than those which are caseous, fibrous, or glutinous. Some substances are very difficult to digest, such as bone, the epidermis of fruits, and entire kernels of grain. In determining the digestibility of aliments, it is necessary to take into consideration the size of the portions which are swallowed. I have often observed that the largest masses remained longest in the stomach. On the contrary, a substance that is not even digestible, if it be minutely divided, as the stones of raisins, do not remain long in the stomach, but pass at once with the chyme into the intestine. As regards facility and promptitude in the formation of the chyme, there is a vast difference among individuals. Sir Astley Cooper made a number of experiments on the digestibility of various aliments. He gave to dogs an ascertained quantity of pork, mutton, veal, and beef, keeping an account of the figure of the morsels, and of the order in which they were swallowed. On opening these animals at the end of a certain time, and examining carefully what remained in the stomach, he satisfied himself that the pork was most rapidly digested, next the mutton, then the veal, and, lastly, the beef. In some of the experiments, the pork and mutton had entirely disappeared, while the beef was scarcely touched. He found, by other experiments, that fish and cheese were very readily digested. The potato was somewhat less digestible; the integument of the leguminous seeds passed into the duodenum without undergoing any alteration. He made similar trials with these substances cooked in different ways, and found, *e. g.*, that boiled

* The pylorus really possesses so few of the qualities with which the imaginations of physiologists have clothed it, that in some animals this opening of the stomach into the intestinal tube is never closed. The horse is an example of this; its pylorus is always freely open. The aliments remain but a short time in the stomach, and are but slightly altered. The true pylorus of the horse is the cardiac orifice of the stomach; its use appears to be to prevent the aliments and drinks from rising in the œsophagus. If we did not keep in mind the free communication between the stomach and intestines, we could not understand how the stomach of the horse, which, in its greatest extension, will contain little more than twelve pints of water, may, however, receive within a short time large quantities of provender and liquid; a bundle of hay and 24 pints of water, for example. The process of digestion in the horse appears to take place through the whole extent of the small, and even in the large intestines. This merits particular attention and special researches.

veal was two thirds more digestible than when roasted. He likewise found that the muscular parts were more digestible than the skin; and the skin, than the cartilages; and the latter, than the bones. With respect to the bones, he found that the sternum was the most digestible; 100 parts of this bone were digested in six hours, while only 30 parts of the femur were digested at the same time. It is evident, then, from what has been said, that, in order to form an estimate of the precise time required for the conversion of all the food contained in the stomach into chyme, it would be necessary to know its quantity, chemical nature, degree of mastication, and the constitution of the individual. It is rare, however, that the transformation of the whole of the aliment into chyme requires more than four or five hours.

We do not know the precise nature of the chemical changes which take place in the stomach, though there have been, at different periods, many attempts to explain them. The ancient philosophers supposed that the aliments putrefied in the stomach; Hippocrates attributed digestion to *coction;* Galen supposed that the stomach possessed certain faculties, which he called *attractive*, *retentive*, *concoctive*, and *expulsive*, and thought he thus gave an explanation of digestion. The doctrine of Galen was received by the schools until the middle of the seventeenth century, when it was attacked and overthrown by the chemical sect of philosophers, who established on its ruins the doctrine of a *peculiar fermentation*, by means of which the aliments were *macerated*, *dissolved*, *precipitated*, &c. This system did not retain its ground long, but was replaced by another much less reasonable. The doctrine which succeeded was that of *trituration*, or a grinding down of the aliments by the contraction of the stomach; it was also supposed that an infinite number of small worms attacked and divided the aliments. Boerhaave thought he had approached nearer the truth when he combined together the various opinions on this subject which had prevailed before his time. Haller abandoned the doctrines of his master, and considered digestion as a simple maceration. He knew that vegetable and animal substances which are plunged in water are soon covered with a coat, soft and homogeneous; and he supposed that the aliments underwent a similar process by being macerated in the saliva and gastric juices.

If we examine these different systems by those severe rules of logic which should always govern us in physiological inquiries, we shall be compelled to acknowledge that they were mere flights of the imagination, which only served to conceal the absolute ignorance of their inventors. Was it any advance in knowledge to say that digestion was a concoction, a fermentation, or a maceration? Certainly not, as it is impossible that any one can attach any precise meaning to these expressions when applied to digestion. But this was not the method pursued by Reaumur and Spallanzani. They made experiments upon animals, and demonstrated that all these systems were false. They showed

that, when aliments were enclosed in hollow metallic balls, pierced with small holes, they were digested in the same manner as if they were floating loose in the cavity of the stomach. They proved that the stomach contains a peculiar fluid, which they called *gastric juice*, and that this fluid is the principal agent in digestion; but they exaggerated its qualities very much, and deceived themselves when they supposed that they had explained digestion by considering it a *mere solution;* for, from their not explaining what they meant by this solution, they, in fact, did nothing towards showing what the precise alteration is which the food undergoes in the stomach.

Instead of stopping to expose and refute these different hypotheses, which would be a very easy task, and which may be found in almost every treatise on physiology, we shall make some observations on the formation of chyme. It is necessary, in investigating this subject, to attend to the following points: *first*, to the circumstances in which the aliments contained in the stomach are found to exist; and, *second*, to the chemical nature of these substances. The circumstances in which the aliments are placed during the time they remain in the stomach which require to be noticed are few in number. *First*, they experience a pressure, more or less strong, of the abdominal walls, and of those of the stomach; *second*, they are affected by the motions of respiration; *third*, they are exposed to a temperature of from 98° to 104°; *fourth*, they are exposed to the action of the saliva, mucus of the mouth, œsophagus, and gastric juice. This last fluid is slightly viscid, but it consists of a considerable portion of water, of mucus, of salts, the base of which is soda and ammonia, and of the lactic acid of Berzelius.

With respect to the nature of the aliments, we have already seen how variable they are, inasmuch as all the immediate principles of animals and vegetables may be carried to the stomach, in different forms and proportions, for the formation of the chyme. Can we, therefore, when we take into consideration the nature of the aliments, and the circumstances under which they are placed in the stomach, account for the phenomena which are known to accompany the formation of the chyme? The particular temperature, the pressure, and the agitation which the aliments undergo, cannot be considered as essential causes of its transformation into chyme; it is probable that they merely assist in the production of this effect. There remain, therefore, the action of the saliva, and of the peculiar fluid secreted by the stomach; but, from the known properties of the saliva, it is incredible that it can attack and change the nature of the aliments, though it may serve the purpose of diminishing the cohesion of their particles. We must, therefore, attribute this remarkable effect to the fluid formed by the internal membrane of the stomach. It appears, then, that this is the agent which, acting chemically on the alimentary substances, dissolves them from the surface towards the centre.

To establish incontrovertibly this point, it has been attempted

to produce what has been called, since the time of Reaumur and Spallanzani, *artificial digestion*. For this purpose, after having masticated the food, it has been mixed with the gastric juice, and afterward exposed, in a tube or other vessel, to the same temperature as that of the stomach. Spallanzani has asserted that they succeeded, and that aliments were reduced to chyme ; but, since the more recent researches of M. Montegre, it appears to be shown that this is not the case, but, on the contrary, that the substances employed did not undergo an alteration at all analogous to that of chymification, which agrees with the experiments of Reaumur. But even if the gastric juice does not dissolve the aliments with which it is enclosed in a tube, we cannot, therefore, conclude, with some, that this fluid does not dissolve the aliment when it is introduced into the stomach. The circumstances are far from being the same. In the stomach, the temperature is equal, the aliment pressed and agitated, the saliva and gastric juice renewed continually ; and, as soon as the chyme is formed, it is forced into the duodenum. There is nothing of all this takes place when the aliment is placed in a tube or a vessel, and then mixed with the gastric juice. The want of success, therefore, in artificial digestion proves nothing with respect to the formation of chyme.

[The circumstances were sufficient, nevertheless, to satisfy many very intelligent physiologists of the accuracy of the observations of Spallanzani, notwithstanding the denial of Montegre. Still, the high authority of the latter was sufficient to leave the subject in doubt, while the difficulty of procuring the gastric juice in a state sufficiently pure left the question long unsettled. An opportunity, however, has occurred, within a few years, of definitively settling this point in this country, which has confirmed to the fullest extent the observations of Spallanzani. The case to which I refer is that of San Martin, formerly a soldier in the United States army, who has a fistulous opening into the stomach, the consequence of a gunshot wound. Dr. Beaumont of the army, under whose care San Martin has been placed, has made a series of important observations on the subject of digestion, an account of which has been published in his very interesting memoir. The fistulous opening into the stomach of San Martin is about the size of a quarter of a dollar. It is necessary to keep it closed by a pad to prevent the escape of the food. The young man enjoys excellent health ; his appetite and digestion are generally good, and he is active in his habits. When the food is removed, the mucous membrane of the stomach is apt to become protruded, so as to present a tumour resembling, in form and colour, a half-blown rose ; but he can return this herniary protrusion, without pain, by a slight pressure. When San Martin is lying on his back, you may look into the cavity of the stomach, and deliberately observe, to a certain extent, the process of chymification. Substances can be introduced through this opening, for the purpose of experiment, without inconvenience, and the accumulated fluids drawn off by means of a siphon.

The work of Dr. Beaumont is the most direct and authoritative which has yet been published, and throws great light on the process of chymification. He possessed, in this case, facilities for exact observation superior to those of any other individual, and his book affords undoubted proof that he had the requisite talents for availing himself of their advantages. It will be remembered that all the facts stated by him are the results of direct observation, not of inference from other facts.

Dr. Beaumont found that the gastric juice in man is transparent, slightly viscid, and somewhat acrid and saltish. It contains pure muriatic and acetic acids, phosphates and muriates, with bases of potassa, soda, magnesia, and lime. He ascertained that this fluid is not formed during the intervals when the stomach is empty. It is without smell, is diffusible in water, wine, or spirit; coagulates albumen and milk; it checks putrefaction; when pure, it keeps for months without decomposition, but, when combined with the saliva, becomes soon fetid. It effervesces slightly with alkalies. But by means of a magnifying glass he was enabled to see the manner in which this fluid is formed. After the patient had been fasting for some time, and the food of the previous meal had been entirely removed, the contact, not only of food, but any other substance, for example, the bulb of the thermometer, when brought in contact with the mucous coat of the stomach, caused the secretion of the gastric juice to take place. The effects were similar, whether the food was swallowed or introduced through the opening of the stomach. The mucous membrane, from its usual pink colour, became more fully injected with blood, and of a deeper red, the contractions of the stomach were excited, the villous coat rose into numerous small vascular papillæ, on which small drops of a thin, pellucid fluid were formed, which he ascertained was the pure gastric juice, which at last trickled down the sides of the stomach, and mingled with the food.

The solvent power of the gastric juice out of the stomach, which was asserted by Spallanzani and denied by Montegre, was incontrovertibly established by Dr. Beaumont by innumerable experiments. He found, as might have been anticipated, that agitation and temperature of the food have a material influence on the process of chymification. It appeared, from the experiments of Dr. Beaumont, that agitation of the food had a decided influence in accelerating the process of solution in all his experiments out of the stomach. This is manifestly one of the objects of the peristaltic motion of the stomach. This motion gently agitates the food, brings successive portions of it to the surface of the stomach, so as to enable it to imbibe the gastric juice, while, at the same time, it throws it and the chyme towards the pylorus. Dr. Beaumont repeatedly found, while examining the stomach with a thermometer, that the food was thus constantly pushed in this direction. To determine the effects of temperature, he divided two ounces of pure gastric juice into equal parts, and placed it in two vials, into each of which he placed equal quantities of fresh

masticated beef. One vial was kept in a bath at 99°, and the other exposed to the open air at 34°. At the end of six hours the meat in the warm vial was half digested, the gastric juice appearing to be incapable of dissolving any more. In the other, neither the meat nor gastric juice had undergone any change.

The fistulous opening was near the upper portion of the great curvature of the stomach, the external opening being about two inches below the left mamma. While San Martin lay upon his back, if pressure was made with the hand in the situation of the liver, and the body turned, at the same time, upon the left side, bile flowed through the pylorus, and could be drawn off by an elastic tube. Sometimes, too, though rarely, bile was found mixed with the gastric juice when the above manœuvre had not been practised. Chyme could readily be procured by applying the hand to the epigastric region, and pressing upward. The stomach, when empty, could be explored to the depth of five or six inches by artificial distention; the food and drink could thus be seen to enter it.

Dr. Beaumont has given a table of the time required for the solution of a great number of different articles of food, describing the article, mode of cooking, meal or period at which taken, how far connected with exercise and rest, together with general remarks. The articles most rapidly digested were tripe and pigs' feet soused, the former fried, the latter boiled, taken at breakfast, exercise moderate. They were completely dissolved in one hour. The articles which required the longest time were salted beef and pork; the latter requiring five hours and fifteen minutes, and the former five hours and thirty minutes. The protracted chymification of the pork appeared to arise from his having become angry during the experiment.

Previous to the publication of Dr. Beaumont's Memoir, a brief notice of this case was published by Dr. Lovel, Surgeon-general of the United States Army. Among a number of interesting experiments were the following:

Experiment 1st.—At 12 o'clock, M., Dr. Lovel introduced through the fistulous opening the following substances, attached to threads, each weighing about two drachms. 1st, à la mode beef; 2d, corned beef; 3d, fat bacon; 4th, raw beef; 5th, boiled; 6th, bread; 7th, raw cabbage stalk. The young man then continued his usual domestic occupations within doors. The materials were examined at the end of an hour. The cabbage stalk and bread were about half digested, but the animal food had undergone no sensible change. All the articles were returned, and at the end of two hours the cabbage, bread, and bacon were entire, while the other aliments were but little altered. At the end of three hours, the à la mode beef was partly digested, the raw and corn beef a little macerated on the surface. The fluids in the stomach were now somewhat rancid to the taste and smell, and the patient complained of some sense of uneasiness in the stomach, with lassitude, general weakness, and headache. The remaining substan-

ces were therefore removed, the two bits of beef being found but little changed. The next day the patient complained of nausea, headache, and constipation; the pulse was depressed, the skin dry, and the tongue coated. The mucous membrane of the stomach, so far as it was visible, presented many white spots like portions of coagulable lymph. Purgation was deemed necessary, and six calomel pills, of grains iv. each, were introduced through the fistulous opening. In three hours they produced full cathartic effect; all the symptoms were dissipated, and the white specks disappeared from the stomach.

San Martin, though generally temperate in his habits, would occasionally indulge to excess in the use of alcoholic drinks for several days in succession. During one of these periodical paroxysms of dissipation, Dr. Beaumont carefully noted the effects. He found the mucous membrane of the stomach covered with erythematous and apthous patches, and all the secretions manifestly morbid in their colour and appearance on the second day. Still, the appetite was not materially impaired. At the expiration of four days, he still continuing to drink to excess of ardent spirit, though he made no complaint of any gastric affection, yet there was a great increase of these morbid appearances. The erythematic and apthous appearance of the mucous membrane had now become very much increased and very extensive, and the spots more livid than before. From the surface of some of these spots there exuded small drops of grumous blood. The apthous patches became larger and more numerous, and all the gastric secretions viscid, and vitiated in their appearance. When the gastric fluids were extracted through the fistular opening, they were found mixed with a large proportion of ropy mucus, and a considerable quantity of muco-purulent discharge slightly tinged with blood, resembling the discharge from the bowels in some cases of dysentery. Still, it is remarkable that the patient made no complaint directly referrible to this much-abused organ, the appetite still continuing tolerably good. The only symptoms of which he complained were slight uneasiness and tenderness of the epigastrium, with some vertigo and dimness of vision on stooping. But the pulse was natural, and the sleep good. At this time he abandoned his pernicious habit, and the organ was soon restored to its normal state.

A question has been raised, and investigated with much zeal and experimental industry, how far the solvent properties of the gastric juice are connected with certain free acids found combined with it. The acetic and muriatic acids have been especially supposed to exert an important influence in this respect. Several of the latest and most competent observers have thought that the essential agency of these acids in the solution of the food in the process of chymification is very improbable. It was long since acknowledged by Berzelius that no investigations with which he was acquainted had revealed the nature of the active solvent principle of the gastric juice; while Müller confessed that every-

thing tended to convince him that the active principle of this solvent is an organic substance, the action of which is similar to that of "*diastase*" on starch. Such were the opinions of Müller previous to the publication of the experiments of Eberle and Schwann on the solvent properties of infusion of the mucous membrane of the stomach combined with dilute acids. From these, as well as a number of experiments instituted by him, both alone and in connexion with Schwann, Müller was induced to change his views, and regard the digestive principle as a peculiar substance, to which, although he confesses it could not be procured in a separate state, he gave the name of *pepsin*, on account of its properties. But the observations and experiments of these learned physiologists, though ingenious and plausible, can scarcely be considered altogether satisfactory or conclusive.*]

How, then, it may be asked, can the same fluid act in a similar manner upon a great number of different substances, varying essentially from each other? The present state of organic chemistry does not furnish a satisfactory reply to this question. But, of all solvents of animal substances, the acetic acid appears most completely to fulfil this condition. The following experiment will illustrate this: take a portion of each of the different tissues of the body, and subject them to the action of the acetic acid, and they will be found to dissolve. This, which takes place in a glass vial, will be much more readily accomplished in the stomach by means of the lactic acid, the resemblance of which to the acetic acid is so striking that chemists have doubted if they could be properly considered as different substances. The solution of the aliments is also favoured by the action of water, and the solvent properties of the hydrochlorates of soda and ammonia.

But though we can easily understand how an acid or alkaline re-agent may dissolve animal or vegetable substances in a glass vessel without attacking the walls of that vessel, yet it is not so easy to understand how the stomach should resist the action of the gastric juice. The explanations of physiologists on this point are vague and unsatisfactory. It is said that this is attributable to *vitality, which repels chemical action*. A few years since this was considered a satisfactory reply; but at present every one perceives that it is a mere play upon words. We know that chemical agents do act upon our organs, both living and dead, and that, in many instances, life favours their action.

This is not, then, a satisfactory explanation of the inactivity of the gastric juice upon the mucous membrane of the stomach. Perhaps it may depend, though I by no means assert it, upon the incessant secretion of mucus during chymification, which is thus continually interposed between the solvent and the walls of the stomach. What seems to confirm this is, that as soon as the secretion is arrested by death, or in any mode much diminished, the gastric juice directs its activity against the stomach itself,

* Editor.

softens the mucous membrane, and sometimes dissolves the muscular and peritoneal coats, and produces perforations, which the ignorance of physicians has attributed to disease. I have seen, in several instances, solutions of this kind in the stomachs of criminals. Having once perforated and dissolved the stomach, the action of the gastric juice sometimes extends, softening and dissolving the neighbouring organs, as the spleen, diaphragm, liver, &c. One of the effects of this chemical action is to change the blood in the arteries and veins, or any that may have been extravasated into the stomach, to a deep black colour.

In general, the process by which the chyme is formed prevents the reaction of the constituent aliments upon each other. But this only takes place where the digestion is good; when bad, fermentation, and even putrefaction, may take place in the stomach. This is indicated by the escape of a great quantity of inodorous gas in some cases, and by the sulphuretted hydrogen which is disengaged in others. Sometimes these gases produce a singular effect during sleep. They arise in the œsophagus, distend and compress the heart at its anterior surface, and so disturb the circulation as to produce a most distressing sensation of anxiety. I am acquainted with a person who relieves himself of this accumulated gas in the œsophagus by introducing his finger into the pharynx, and opening the tube so as to permit its escape, and which sometimes takes place with an explosion, which affords immediate relief.

For a long time the nerves of the eighth pair were regarded as presiding over chymification. Indeed, if we tie or cut these nerves in the neck, the substances introduced into the stomach do not undergo the same change as while these nerves remained intact. This effect, which is most striking in herbivorous animals, has been carefully examined by M. Dupuy, professor in the Veterinary School of Alfort. The imperfection or difficulty of gastric digestion appears, in this case, to arise from the cessation of the secretion of the gastric juice. But it has been inferred, generally, that the division of the eighth pair abolishes the power of chymification. This seems to me too strong a conclusion; for the division of the eighth pair induces such disorder in the respiration and pulmonary circulation, that perhaps the derangement of the digestion may be chiefly the effect of the lesion of these two important vital functions.*

To avoid this difficulty, I divided these nerves, not in the neck, as had been done in preceding experiments, but in the thorax, immediately above the diaphragm. For this purpose, I divided one of the sternal ribs, tied the intercostal artery, and, introducing my finger into the chest, I raised the œsophagus, and the nerves spread upon its surface. It was then easy for me to cut them. Some time after the division had been made, I compelled the animal to eat aliments the chymification of which is familiar to me, *e. g.*, fatty substances. I found, after due time had elapsed, that

* See the Influence of the Eighth Pair on Respiration.

these substances had undergone chymification, and furnished abundant chyle. Division of the eighth pair of nerves also but little impairs the formation of chyme in birds. As, however, it does not appear that these animals have true chyle, but little can be inferred respecting nervous influence in the production of this fluid.

It has been pretended that electricity may exert an influence in the production of chyme, and that the nerves of the stomach may be its conductors. Dr. Wilson Philip first experimented on this subject, and has perseveringly maintained this opinion, alleging in its support numerous experiments. He divided the pneumogastric nerves in two animals after they had eaten heartily. He left one undisturbed, but subjected the other to a galvanic current, passing through the œsophagus and stomach. In the first, digestion was abolished ; in the second, it went on as if the nerves had not been divided. Such are the results as stated by Dr. Philip. But we may remark, that they are not uniform ; and that they have often failed even with Dr. Philip himself, which would certainly not have happened if digestion were a simple physical phenomenon. Again, the simple section of the nerves, even in the neck, do not always absolutely interrupt chymification. The recent experiments in Paris by Messrs. Breschet, H. Edwards, and Vavasseur, have led these authors to believe that it only weakens it. We may infer, then, that the influence of the eighth pair of nerves on chymification is not at present precisely understood, and that the galvanic influence upon this nerve is very doubtful.

The probable use of the eighth pair of nerves is to form an intimate relation between the stomach and the brain, so as readily to detect the introduction of injurious substances with the aliments, and to ascertain if they are of a nature to be digested.

In a person in robust health the chyme is formed without his consciousness. He only perceives that the sensation of fulness, produced by the distension of the stomach, gradually disappears. But if the health be delicate, the digestion is accompanied with some dulness in the organs of sense, coldness, and slight chills ; the mind is often torpid, and the individual disposed to sleep. It is said, in these cases, that the vital forces are concentrated upon the acting organ, and, for a time, are less energetic in others. To these general effects we may add the formation of gas, which escapes by the mouth, a sensation of weight, heat, and vertigo ; at others, of burning, followed by a similar sensation along the œsophagus, &c. These sensations are most frequently felt towards the end of chymification ; they appear to result from a true fermentation in the stomach. Similar phenomena occur if the aliment be left for some time exposed to a temperature of about one hundred degrees of Fahrenheit's scale. This slow digestion does not always appear, however, to be less beneficial than when more prompt. The character of acidity which enables the gastric juice to act upon albumen, for example, would seem to render it incapa-

ble of dissolving fatty substances. But to this it may be replied, that it has not been proved that the gastric juice is always the same. The small number of analyses which have been made prove, on the contrary, that its properties vary considerably. It is possible that the contact of different aliments with the mucous membrane of the stomach may have an influence upon its composition; it is certain, at any rate, that it differs in different animals. That of man, for example, is incapable of attacking the tissue of the bones, while the dog digests these substances perfectly.* In general, the action by which the chyme is formed prevents the reaction of the constituent elements of the food upon each other; but this is only true when the digestion is good. It is found, when the powers of digestion are impaired, that fermentation, or even putrefaction, may take place. There seems reason to believe that the great quantity of inodorous gas which is thrown off, in some cases, and the sulphuretted hydrogen which is disengaged in others, is attributable to this cause.

Action of the Small Intestine.

This is the longest portion of the canal, and establishes a communication between the stomach and large intestines. It is incapable of great distention, has numerous convolutions, and is very long. It is attached to the vertebral column by a fold of the peritoneum, which allows of free motion, but, at the same time, limits it. Its longitudinal and circular fibres are not separated, as in the stomach; its mucous membrane, which presents numerous villosities, and a large number of mucous follicles, forms folds, irregularly circular, the number of which increases as we examine the intestines near the pyloric orifice; these folds are called *valvulæ conniventes.* The small intestines are very vascular; their nerves arise from the ganglions of the great sympathetic. The lacteal vessels open upon their internal surface by very numerous orifices.

This intestine has been divided into three parts, which are distinguished by the names of *duodenum*, *jejunum*, and *ilium;* a distinction of but little use in physiology. Like the mucous membrane of the stomach, the small intestines secrete an abundance of mucus; I do not think it has ever been analyzed. I have found it to be viscid, of a saltish taste, and to change the vegetable purple colours red; properties which we have before noticed in the fluid secreted by the stomach. Haller gave to this fluid the name of *intestinal juice;* it has been estimated that eight pounds of this fluid are formed in twenty-four hours. At a short distance from the pyloric orifice of the stomach is found the common orifice of the biliary ducts and the pancreatic duct, by which the fluids secreted by the liver and pancreas pass into the cavity of the intestine. If the formation of the chyme is still a mystery,

* We should be careful, however, lest we admit too much as respects those conjectured variations of the animal fluids. The more perfect the science of chemical analysis becomes, the more constant we find the composition of vegetable and animal substances to be.

the nature of the phenomena which take place in the small intestines is by no means better understood. We shall confine ourselves still to the plan which we have adopted; that is, we shall content ourselves with describing what observation has proved to us. We shall first speak of the introduction of the chyme into the small intestines, and afterward of the alterations which it undergoes there.

Accumulation and Passage of the Chyme into the Small Intestines.

I have often had occasion to observe in dogs the chyme passing from the stomach into the duodenum. The following are the phenomena which I have remarked. At intervals more or less remote, we see a contractile motion take place towards the middle of the duodenum; this is rapidly propagated towards the pylorus; this ring itself contracts, as well as the pyloric portion of the stomach. In consequence of this movement, the substances contained in the duodenum are thrust towards the pylorus, where they are stopped by the valve; and those which are contained in the pyloric portion of the stomach are forced towards the cardiac. But this motion, directing the intestine towards the stomach, is soon replaced by a motion in the opposite direction; which is propagated from the stomach towards the duodenum, and which forces from the pylorus a certain quantity of chyme. It appears to me, then, that the valve of the pylorus serves the purpose both of preventing the substances contained in the small intestines from flowing back into the stomach, and also of retaining the chyme and the aliments in the cavity of this organ.

This motion is repeated, generally, several times in succession, varying in the frequency and intensity of the contractions; after which it ceases for some time. It is not very distinctly marked when the formation of the chyme begins, as the extremity only of the pyloric portion partakes in it. It augments as the stomach becomes empty, and towards the end of chymification I have frequently seen the whole of this organ partake in the action. I have ascertained that this motion is not suspended by the division of the nerves of the eighth pair. This is of great importance as respects the nervous action of these parts. It proves that the functions of these nerves cannot be compared, as has been generally done, to those of the common motor nerves. Paralysis follows immediately upon the division of the latter. But nothing of this takes place in the stomach; the contractions of this organ lose more of their activity, at least at first. Thus, the entrance of the chyme into the small intestine is not continuous. In proportion as it is repeated, the chyme becomes accumulated in the first portion of the small intestines; it distends a little their walls, spreading itself over the intervals of the *valvulæ conniventes*. Its presence soon excites the organ to contract, and, by this means, a part is thrown farther into the intestine. and the rest remains attached to the surface of the membrane, and takes soon after the same di-

rection. The same phenomenon is continued into the large intestines; but as the duodenum receives new portions of chyme at a certain period in the process, the small intestines are filled with this matter through their whole extent. We observe, however, that it is much less abundant in the neighbourhood of the cœcum than at the extremity of the pylorus.

The motion which impels the chyme through the small intestines has a very great analogy to that of the pylorus. It is irregular, returns after unequal periods, is made sometimes in one direction and sometimes in another, and is manifest often in several parts at the same time. It is always slow, and alters the relations of the intestinal convolutions; it is entirely free from the control of the will. We should form very incorrect ideas on this subject if we confined ourselves to the examination of the small intestines in an animal recently killed. It displays then a degree of activity far greater than during life. But in persons with impaired digestion, it acquires an activity and energy not generally observed during health. Whatever may be the manner in which this motion is executed, the progress of the chyme through the small intestines is very slow; the numerous valves already noticed, the many asperities projecting from the surface of the mucous membrane, and the multiplied curvatures of the canal, must all have the effect of retarding its progress, but must favour its admixture with the fluids contained in the intestine, and the production of the chyle which results from it.

Changes which the Chyme undergoes in the Small Intestines.

The chyme is not changed in its sensible properties until it arrives at the orifice of the *ductus communis choledochus*, and the excretory duct of the pancreas. Thus far, it preserves its colour, semi-fluid consistence, sharp odour, and slightly acid taste; but, on being mixed with the bile and pancreatic juice, it acquires new characters. Its colour becomes yellowish, its taste bitter, and its sharp odour essentially diminished. If it consist of animal or vegetable substances, containing fat or oil, there will be seen to form here and there upon its surface irregular filaments, flattened or rounded, which attach themselves to the surface of the valvulæ conniventes, and appear to be imperfectly-formed chyle. We do not remark this when the chyme consists of aliments which do not contain oil. There is also a grayish coat that adheres to the mucous membrane, which appears to be the elements of the chyle. The same phenomena are observed in the two superior thirds of the small intestines; but in the inferior third, the chyme acquires a greater degree of consistence; its yellow colour assumes a deeper tint; and it often becomes, at last, of a greenish brown, which pierces through the intestinal walls, and gives to the ilium an appearance different from the duodenum and jejunum; when the cœcum is examined, we shall find whitish striæ; these appear to be nothing more than the residue of the substances which have served for the formation of the chyle.

From what has been said of the varieties which the chyme exhibits, it will be perceived that the changes which it undergoes in the small intestines must vary, according to its properties. Indeed, the phenomena of digestion in the small intestines vary with the nature of the aliment.* The chyme, however, preserves its acid property, and if it should happen to contain fragments of aliments, or other substances which have resisted the action of the stomach, these pass through the small intestines without undergoing any change. The same phenomena take place when the same substances are employed. I have recently satisfied myself of this by examining the bodies of two criminals, who, two hours before their execution, had eaten the same kind of food, in nearly equal quantities. The substances contained in the stomach, the chyme in its pyloric portion, and in the small intestines, appeared to me precisely similar in consistence, colour, taste, and odour, &c.

Dr. Prout has carefully examined the composition of the chyme. His experiments were made on different kinds of animals. He compared the digestion of two dogs, one of which had eaten exclusively vegetable, and the other animal substances. The result of these comparative analyses may be seen in the following table:

The Chyme taken from the Duodenum of the first Dog.

The general appearance was semi-fluid, of a light yellow, mixed with another part of the same colour, but of a greater degree of consistence, coagulating milk.

When analyzed, it was found composed of the following ingredients:

Water	86.5
Chyme, &c.	6.
Albuminous matter	0.0
Biliary principle	1.6
Vegetable gluten	5.0
Salts	0.7
Insoluble residuum	.2
	100.0

The Chyme taken from the Duodenum of the second Dog.

Thicker, and more viscid than that from vegetable aliment; its colour inclined to reddish; did not coagulate milk.

Water	81.0
Chyme, &c.	15.0
Albuminous matter	1.3
Biliary principle	1.7
Vegetable gluten	0.0
Salts	0.7
Insoluble residuum	0.3
	100.0

* We have made many experiments on this subject, but it would have been improper to have detailed them in a work professedly elementary.

The inquiry naturally arises, if an aliment be not subjected to the action of the stomach, but if it be placed within the influence of the small intestines, will it be digested? I have made various attempts to solve this interesting question, particularly in a medical point of view. First, we may observe that persons whose stomachs have been completely disorganized often live so long that we might suppose that the cessation of the action of the organ does not interrupt entirely the digestive process. I placed in the duodenum of a dog in good health a small portion of raw meat. At the end of an hour it was expelled from the rectum, little diminished in weight, or altered upon its surface except in colour. In another experiment, I attached a morsel of muscle so that it could not pass out of the small intestines. Three hours afterward the animal was opened. The piece of meat had lost about half its weight; the fibrine had been particularly attacked; the cellular tissue, which chiefly remained, was extremely fetid. Hence there may be a solvent property in the fluid secreted by the small intestines.

According to Messrs. Tiedemann and Gmelin, the intestinal juice of which we have spoken dissolves certain remains of the aliments which pass from the stomach into the small intestines; this same juice is absorbed in part by the dissolved aliments, and communicates to them qualities by which they are more nearly approximated to the blood. Its mucous portion being more consistent, forms the excrements, uniting them with the resin, fatty matter, mucus, and colouring principle of the bile.

It is rare that we do not meet with gas in the small intestines during the fermentation of the chyle. M. Jurine, of Geneva, was the first person who examined this subject with attention, and pointed out the nature of the gases; but at the period that this learned physician wrote, eudiometrical processes were far from having acquired the degree of perfection at which they have since arrived. I was, therefore, induced to make some new experiments on this interesting subject. M. Chevreul assisted me in executing this undertaking. Our experiments were made on the bodies of two criminals opened a short time after death, and who, having been young and vigorous, were extremely favourable to these researches. In one, twenty-four years of age, who had eaten, two hours before execution, bread and cheese, and drank red wine, we found in the small intestines,

Carbonic acid	24.39
Hydrogen	55.53
Azote	20.08
Total	100.00

In a second subject, twenty-three years of age, who had eaten of the same food at the same time, and who had been executed at the same time, we found,

Carbonic acid	40.00
Hydrogen	51.15
Azote	8.85
Total	100.00

In a third experiment, made upon a young man twenty-eight years of age, and who had eaten, four hours before his execution, bread and beef, and lentils, and drank red wine, we found in the small intestines,

Carbonic acid	25.00
Hydrogen	8.40
Azote	66.60
Total	100.00

We have never observed any other gas in the small intestines. This gas may be produced in different ways: it may come from the stomach with the chyme; it may be secreted by the mucous membrane of the intestines; it may be produced by the reciprocal action of the substances contained in the intestine; or, perhaps, it may arise from all these three causes combined. The stomach, however, contains oxygen, with very little hydrogen; while, in the small intestines, we have uniformly met with a considerable portion of hydrogen, but no oxygen. Daily observation shows, also, that whenever the stomach contains gas, it is discharged by the mouth towards the end of chymification, probably because at this time it most readily passes into the œsophagus. The secretion of gas by the mucous membrane is not known to take place, except carbonic acid gas, which appears to be performed in this manner during respiration.

With respect to the reciprocal action of the substances contained in this intestine, I have often observed air-bubbles to escape rapidly from the chyme. This phenomenon has taken place from the orifice of the *ductus communis choledochus*, to the commencement of the ilium, but no trace of it can be perceived in this intestine, nor in the superior part of the duodenum or stomach. I made this observation on the body of a criminal four hours after death; it did not present any trace of putrefaction. The alteration that the chyme undergoes in the small intestines is unknown; it is evident that it is the result of the action of the bile, pancreatic juice, and of the fluid secreted by the mucous membrane;* but what is the precise nature of the affinities exerted in this operation, which may be considered truly chemical, and how the chyle comes to be precipitated upon the surface

* Mr. Brodie made some experiments on the use of the bile in digestion. He tied the ductus communis choledocus in newborn kittens; this prevented the formation of chyle. The chyme passed into the small intestines without depositing what I have called the crude chyle. The lacteal vessels did not contain chyle, but only a transparent fluid, which Mr. Brodie supposed was composed partly of lymph and partly of a liquid portion of the chyme. I have repeated this experiment on grown animals; most of them died in consequence of opening the abdomen, and the necessary manipulations. But in two cases, in which the animals survived some days, I satisfied myself that the digestion had continued, that the chyle had been formed, and stercoraceous matter produced. The latter was not coloured, as usual. This was not to be expected, as it contained no bile. The animals did not become yellow.

of the *valvulæ conniventes*, while the surplus remains in the intestine, to be at last thrown out of the system, is a question of which we are completely ignorant. We know but little of the time required for the chyme to be sufficiently altered; but it does not take place very rapidly. In animals, three or four hours after eating, it often happens that we do not find that the formation of the chyle has taken place.

From what has been said, it will be seen that the chyme in the small intestines is divided into two parts. The one is attached to the walls, and is the chyle in an imperfect state; the other is destined to be pushed into the large intestines, and at last entirely rejected. Thus is accomplished that most important part of digestion, the production of chyle.

Action of the Large Intestines.

This organ is of considerable extent; it passes over a long circuit between the right iliac region, where it commences, and the anus, where it terminates; it is divided into *cæcum*, *colon*, and *rectum*. The cœcum is situated in the right iliac region, and is connected with the small intestines. The colon is subdivided into an ascending portion, which extends from the cœcum to the right hypochondrium, a transverse portion, which passes horizontally from the right to the left hypochondrium, and a descending portion, which is prolonged to the cavity of the pelvis. The rectum is very short; it begins where the colon finishes, and terminates in the anus.

The large intestine is bound down by folds of the peritoneum, disposed so as to allow of variations in its volume. Its muscular coat has a peculiar arrangement. Its longitudinal fibres form three narrow bands, very distant from each other when the intestine is dilated. Its circular fibres, also, are formed into bands, much more numerous, but also separated. The result is, that at a great number of points, the intestine is only formed by the peritoneum and the mucous membrane. These places are generally arranged into distinct cavities, where the fecal matter accumulates. The rectum alone does not exhibit this structure; its muscular coat is very thick and uniform, and appears to contract with great energy.

The mucous membrane of the large intestine is not, like the small intestine, covered with *villi*, but is, on the contrary, smooth, its colour of a pale red, and we find on it but few follicles. At the place of its junction with the small intestines, there is found in the cœcum a valve, evidently intended to allow substances to pass into this intestine, but to prevent their return into the small intestine; there is a smaller number of arteries and veins distributed to this organ than to the small intestines; the same remark also applies to the nerves and lymphatics.

Accumulation and Passage of the Fecal Matter into the Large Intestines.

By the contraction of the inferior portion of the ilium, the matter contained in it is made to pass into the cœcum. This motion is very irregular, and returns at distant intervals. It is seldom remarked in living animals, but may be frequently seen in those which are killed suddenly. It does not in any way resemble the action of the pylorus. In proportion as this motion is repeated, the matter contained in the ilium becomes accumulated in the cœcum. It cannot return into the small intestines, in consequence of the valve of the cœcum, and can only pass through the opening which communicates with the colon. Having once passed into the cœcum, it receives the following names: *fecal*, or *stercoraceous matter*, *fæces*, and *excrement*, &c. After remaining some time in the cœcum, the fecal matter passes into the colon, and traverses, successively, its different portions; sometimes forming one continued mass, and sometimes forming distinct masses, which fill one or more of the cavities which the intestine presents through its whole length.

The progress of the fecal matter is almost always very slow; it is effected by the contraction of its muscular fibres, and the pressure which the intestine suffers as one of the abdominal viscera; and it is favoured, also, by the mucous secretion of its internal membrane. Having arrived at the rectum, the matter accumulated there distends its walls, and forms, often, a mass of several pounds; it cannot pass beyond this, as the anus is habitually closed by the contraction of the two sphincter muscles. The consistence of the fæces in the large intestines is very variable, but, in a person in good health, it is always greater than in the small intestines. Generally, its consistence increases as it approaches the rectum, but it is made softer by the fluids which the mucous membrane secretes.

Changes of the Fecal Matter in the Large Intestines.

Before penetrating into the large intestines, this matter does not exhibit the fetid odour peculiar to the human excrement; but it contracts this odour, however short the time it remains there. Its colour, a brownish yellow, becomes also deeper, but, with respect to consistence, odour, colour, &c., there are many varieties, according to the nature of the food, the manner in which chymification and chylification have been performed, the peculiar constitution of the individual, or the state of his health during the preceding digestion; there is found in the excrement all those substances which have not been changed by the action of the stomach; we often find there stones of fruit, grain, and other substances. Many celebrated chemists have analyzed the human fæces. M. Berzelius found them composed of

Water	73.3
Vegetable and animal remains	7.0
Bile	0.9
Albumen	0.9
Peculiar extractive matter	2.7
Matter formed from bile, resin, animal matter, &c.	14.0
Salts	1.2
Total	100.0

The results observed by Dr. Prout, in the series of experiments above referred to, on the comparative contents of different portions of the alimentary canal, in animals fed exclusively on vegetable and animal substances, were as follows:

FED ON VEGETABLES.	ON ANIMAL SUBSTANCES.
Substances from the Cœcum.	*Substances from the Cœcum.*
Of a brownish yellow, hard and viscous; does not coagulate milk.	Brown, very viscous, and coagulates milk.
Water; quantity indeterminate.	Water; quantity indeterminate.
Mixture of mucous principles and altered alimentary substances, insoluble in acetic acid, and forming a great part of the substance.	Mixture of mucous principles and changed alimentary substances, insoluble in acetic acid, and forming a great part of the substance.
No traces of albuminous matter.	Traces of albuminous matter.
Biliary principles altered as respects quantity nearly as above.	Biliary principles altered as regards quantity nearly as above.
Vegetable gluten? No traces; contained a principle soluble in the acetic acid, abundantly precipitated by the oxalate of ammonia.	Vegetable gluten? No traces; contained a principle soluble in the acetic acid, abundantly precipitated by the oxalate of ammonia.
Saline substances as above.	Saline substances as above.
Insoluble residuum in small quantity.	Insoluble residuum in small quantity.
Substances from the Colon.	*Substances from the Colon.*
Of a brownish yellow colour; of the consistence of mustard; containing many air-bubbles; of a slight odour, but peculiar; analogous to that of fresh paste. Does not coagulate milk.	Consisting of a brownish, tremulous fluid, with whitish substances swimming in it, analogous to coagulable albumen; odour slight, somewhat fetid, resembling bile. Coagulates milk.
Water; quantity indeterminate.	Water; quantity indeterminate.
Mixture of mucous principles and alimentary substances changed; the latter in excess; insoluble in the acetic acid, and forming the principal part of the substance.	Mixture of alimentary substances in excess and of mucous principles; insoluble in the acetic acid, and forming the greater part of these substances.
Albuminous matter, no traces.	Albuminous matter, no traces.
Biliary principles as above, in all respects.	Biliary principles as above.
Vegetable gluten? None. Contains a principle soluble in acetic acid, and precipitated abundantly by the oxalate of ammonia, as with the cœcum.	As above described in the cœcum.
Salts, as above.	Salts, as above described, besides some traces of an alkaline phosphate.
Insoluble residuum; less than in the cœcum.	Insoluble residuum; a solid substance in very small quantity.
In the Rectum.	*In the Rectum.*
Of a firm consistence, and of a brown olive colour, approaching yellow; odour fetid; does not coagulate milk.	Fæces hard, of a brown colour, approaching chocolate; odour very fetid; water, which dissolved coagulated milk.
Combination of alimentary substances altered, in greater excess than in the colon, and of a little mucus insoluble in the acetic acid, and forming the greater part of the fæces.	Combination of altered alimentary substances in much greater excess than in any other analysis, and a little mucus; insoluble in the acetic acid, and forming the greater part of the fæces.
Albuminous matter?	Albuminous matter?
Biliary principles in part changed into resin.	Biliary principles greater than in the fæces from vegetables, and entirely changed in the resinous matter.

Vegetable gluten? None. Contains a principle similar to that in the cœcum and colon.
Salts, as above.
Insoluble residuum, consisting principally in vegetable fibres and hairs.

Vegetable gluten? No traces. Contains a principle similar to that in the cœcum and colon.
Salts, as above.
Insoluble residuum, consisting chiefly in hairs.

These analyses, made with the intention of throwing light on the mysterious nature of digestion, afford us but feeble assistance. In order to give us any considerable advantage, it would be necessary to have the circumstances very much varied; to know exactly the nature and quantity of food that had been used, to keep in view the constitution of the individual, and to analyze only the fæces which had been formed from very simple alimentary substances. But an undertaking of this kind supposes a degree of perfection in our means of analysis at which animal chemistry has not yet arrived.

There exists, also, in the large intestines, gases, enclosed with the fecal matter. M. Jurine long since determined their nature, but he has only made one satisfactory experiment on this subject. In the large intestines of a drunken person found frozen to death, and opened as soon as convenient, he ascertained the existence of azote, carbonic acid, carburetted and sulphuretted hydrogen. M. Chevreul and myself examined with care the gas found in the large intestine of those criminals of whom we have before spoken. In the subject of the experiment first cited, the large intestine was found to contain, in a hundred parts of gas,

Carbonic acid	43.50
Hydrogen, carbon, and some traces of sulphuretted hydrogen	5.47
Azote	51.03
Total	100.00

The subject of the second experiment exhibited, in the same intestine,

Carbonic acid	70.00
Hydrogen and carburetted hydrogen	11.06
Azote	18.94
Total	100.00

In the subject of the third experiment, we analyzed separately the gas found in the cœcum and the rectum; the following are the results:

Cœcum.

Carbonic acid	12.50
Hydrogen	7.50
Carburetted hydrogen	12.50
Azote	67.50
Total	100.00

Rectum.

Carbonic acid	42.86
Carburetted hydrogen	11.18
Azote	45.96
Total	100.00

Some traces of sulphuretted hydrogen were manifested on the mercury before this gas was analyzed.

These results, which may be depended on, inasmuch as every precaution was taken to prevent error, agree very well with those that had been made long before by M. Jurine; but they invalidate his assertion respecting the carbonic acid, the quantity of which, according to this physician, diminished from the stomach to the rectum; but we see, on the contrary, that the proportion of this acid increases as you go from the stomach. The same doubts which we express respecting the origin of the gas in the small intestines may be applied to that produced in the large. Is it received from the small intestine, or is it secreted by the mucous membrane, or formed by the reaction of the constituent principles of the fecal matter, or does it arise from this triple source? It is not easy to remove these doubts.

We may, however, remark, that this gas differs from that in the small intestines. In this last, hydrogen predominates, while in the large intestines it does not exist, but instead of it, carburetted and sulphuretted hydrogen.

I have seen, besides, frequently, gas passing out in the form of innumerable small bubbles from the substance contained in the large intestine.

From what has been said, we may conclude that the action of the large intestines is of little importance in the production of the chyle. It fulfils sufficiently well the office of a reservoir, where are deposited, for a certain time, the residue of the chemical operations of digestion, to be afterward expelled. I conceive that the digestion is completely effected without the large intestines taking any part of it. Nature presents this disposition in those individuals who have an artificial anus, which passes out at the cœcal extremity of the small intestine, and from which those substances escape that have assisted in the formation of the chyme.

Expulsion of the Fecal Matter.

The principal agents in the expulsion of the fecal matter are the diaphragm and abdominal muscles; the colon and rectum co-operate, but, generally speaking, not in a very efficient manner. As long as the fecal matter is not accumulated in the large intestines, especially in the rectum, we are not conscious of its existence; but when it is collected in this part in considerable quantity, it distends the rectum, and produces a vague sensation of fulness and uneasiness over the whole abdomen. This sensation is soon replaced by another, much more vivid, which gives us notice of the necessity of voiding the fecal matter. If this notice be neglected, it often ceases for a considerable time; at others, the sensation is too urgent to be resisted, and the excrement must be discharged, notwithstanding all our efforts to prevent it. The consistence of the fecal matter has an influence upon the vivacity of this sensation. It is almost impossible to resist it if this matter

be very fluid, but it is easily overcome when the contents of the rectum are hard.

There is nothing easier to comprehend than the mechanism of the expulsion of the excrement. In order that this may be effected, all that is required is, that the fecal matter accumulated in the rectum should be pushed forward with a force superior to the resistance which the muscles of the anus present. The contraction of the rectum alone cannot produce this effect; notwithstanding the great thickness of its muscular coat, it is necessary that some other power should co-operate. This is effected partly by the diaphragm, which acts directly from above, downward, upon the whole mass of the abdominal vicera, and by the abdominal muscles, which press them against the vertebral column. From these combined forces there results a considerable pressure, which forces forward the stercoraceous matter collected in the rectum; the resistance of the sphincter is overcome; it relaxes, and the matter contained in the rectum is voided by the anus. But as the cavity of the rectum is much more spacious than the opening of the anus, which has a constant tendency to contract, the matter passing out through this opening will be moulded to its size and form. It will pass the more readily when its consistence is little, but when the reverse is the case, great force is required to expel it. When it is very fluid, the contraction of the rectum alone seems sufficient for this purpose.

A phenomenon analogous to what we have noticed in the œsophagus has been observed in the rectum by M. Halle. This learned professor has remarked, that during the efforts to void the fecal matter, the internal membrane of the rectum is displaced and forced down, so as to form a sort of hood near the anus. This effect must, in a great measure, be produced by the contraction of the circular fibres of the rectum.

The desire of voiding the excrement returns after different intervals, according to the quantity and nature of the aliments employed, and the constitution of the individual; generally, it does not take place until after several consecutive meals. In some persons it takes place once or twice in the twenty-four hours; but in others, who still enjoy good health, this evacuation does not take place oftener than once in ten or twelve days. Habit is one of the causes which has most influence on the regular return of the excretion of the fecal matter. When this habit is established, it returns, with great exactness, at the same hour. Many persons, particularly females, are compelled to have recourse to artificial means, as *enemata*, &c., to assist them in performing this function.

The expulsion of the gas is not periodical. Its progress is much more rapid and irregular. Its displacement being very easy, it arrives very soon at the anus, by the peristaltic motion of the large intestine only. It is, however, often necessary for the abdominal walls to contract in order to expel it. But the expulsion of gas *per anum* is neither regular nor constant. In many persons this but rarely takes place, while in others it is very frequent. The use of certain aliments has an influence upon its formation; its

production to any considerable extent is considered as indicating a bad digestion.

With the expulsion of the fecal matter, this complex function, the end of which is the formation of the chyle, is accomplished. But we should have fulfilled our task very imperfectly if, according to the example of many distinguished authors, we should limit ourselves to treating of the digestion of aliments. There is another consideration which presents itself for our investigation; this is the digestion of liquid aliments, or drinks.

Of the Digestion of Drinks.

It is very remarkable that, though physiologists have devoted much time to investigating the digestion of solid aliments, have invented systems to explain it, and experiments to illustrate it, yet they have never given any attention to the digestion of drinks, although the subject presents less apparent difficulty. Drinks are generally much more simple than solid aliments, and are, for the most part, nourishing and easily digested. The circumstance that we digest drinks should have been considered alone sufficient for rejecting the systems of trituration and maceration. Indeed, we see that drinks can neither be bruised nor macerated, though they remove hunger, restore vigour, and, in a word, *nourish* the body.

Of the Prehension of Drinks.

The prehension of drinks may be executed in a variety of ways; but Petit has shown that they may be referred to two principal modes.* In the first, we pour the drink into the mouth, which is effected by the specific gravity of the fluid. Our common way of drinking must be referred to this mode when we raise the vessel to our lips, and place them in contact with it, and pour the fluid into the mouth. The action of *gulping*, which consists in pouring into the mouth the whole contents of the glass, and drinking *à la régalade*, in which the head is thrown back, the jaws separated, and the fluid poured into the mouth in a continued stream, belong also to this mode. In the second, we cause a vacuum to take place in the cavity of the mouth, the pressure of the atmosphere, at the same time, forcing the fluid to penetrate into it; as, for example, in the act of *sipping* or *sucking*. When we intend to *sip* a fluid, it is executed in the following manner: the mouth is applied to the surface of the fluid; we then enlarge the chest, by which the pressure of the atmosphere upon the portion of the surface of the fluid intercepted by the lips is diminished, and the fluid, therefore, rises into the place of the air which has been drawn from the mouth.

In the act of *sucking*, the mouth resembles an airpump, the *opening* of which is formed by the lips, the *body* by the cheeks, palate, &c., and the *piston* by the tongue. We apply the lips accurately about the body from which we intend to extract the fluid,

* *Vide* Mémoires de l'Académie des Sciences, années 1715–16.

the tongue being also in contact with it; the tongue then contracts itself, by which it is carried backward, and its volume diminished; a vacuum is thus formed between its superior surface and the palate; the fluid contained in the body which we suck, being compressed unequally by the atmosphere, is displaced, and fills the mouth. Neither mastication nor saliva being required for the digestion of drinks, it is not necessary that they should remain long in the mouth; they are, therefore, swallowed as soon as they are received. They undergo no other change in passing through this cavity but that of temperature. If, however, the taste be too strong or disagreeable, or if, finding it agreeable, we are desirous of prolonging the pleasure, the presence of drink in the mouth then causes a discharge of saliva to take place, which is mixed with the fluid.

Of the Deglutition of Drinks.

We swallow fluids in the same manner as solid aliments; but as fluids glide more easily over the mucous membrane of the palate, tongue, and pharynx, and as they yield readily to the slightest pressure, they therefore possess all the qualities which are required for passing rapidly through the pharynx, and are generally swallowed with much less difficulty than solid aliments. I know not why the contrary opinion so generally prevails. It is supposed that the particles of fluids, having a constant tendency to separate, must present a greater degree of resistance to the action of the organs of deglutition; but daily experience disproves this opinion.

Any one may easily prove upon himself that it is easier to swallow fluid than solid aliments, even after they have been fully masticated and impregnated by the saliva.* We may call the portion of aliment swallowed during each motion of deglutition a *morsel.* These vary much in volume, but, however large they may be, when they consist of fluids, they accommodate themselves readily to the form of the pharynx and œsophagus, and, therefore, never produce any painful distention of these passages, as is often observed to take place from solid aliments. In the common method of drinking, the deglutition of fluids exhibits the three stages of which we have before spoken, except in *gulping*, or drinking *à la régalade*, when the fluid is poured directly into the pharynx, and the last two stages only take place.

Of the Accumulation of Drinks in the Stomach, and of the Time they remain there.

They differ little, in this respect, from solid aliments. Their action is generally more prompt, more equal, and easier; probably because the fluids spread themselves, and distend the stomach more uniformly. Like the solid aliments, they occupy more particularly the left and middle portion of the stomach, the right or pyloric portion seldom containing much fluid. The distention

* The manner in which deglutition is performed during disease may be alleged as a proof of this. In severe inflammation of the throat, the patient can only swallow fluids.

of the stomach by fluid cannot be carried suddenly to a great extent, because it will be rejected by vomiting. This accident frequently happens to persons who swallow, in a short period, a large quantity of drink. When a person who has taken an emetic wishes to hasten vomiting, there is no better method of effecting this than by swallowing suddenly several glasses of fluid. The presence of drink in the stomach produces effects similar to those which we have described under the article *Accumulation of Aliments.* The same changes in the form and position of the organ, the same distention of the abdomen, the same obstruction of the pylorus and contraction of the œsophagus, are observed in both.

The general phenomena are different from those which are produced by the solid aliments. This arises from the action of the fluids upon the walls of the stomach, and the promptitude with which they are carried into the blood. The fluids passing more rapidly through the mouth and œsophagus than the solid food, preserve more perfectly their original temperature when they arrive in the stomach. It arises from this that we prefer fluids when we wish to produce in this organ a sensation of heat or cold; and it is for this reason that we give a preference in winter to warm drinks, and in summer to cold ones. It is well known that drinks remain a much shorter time in the stomach than the solid aliments, but the mode in which they pass out from this viscus is but imperfectly understood. It is generally believed that they traverse the pylorus, and pass into the small intestines, from which they are absorbed with the chyle. When a ligature, however, is passed around the pylorus, so as to prevent their passing into the duodenum, it does not essentially retard their disappearance from this cavity. We shall insist more on this important point when we come to speak of the absorption of drinks.

Alteration of Drinks in the Stomach.

In this respect, drinks may be divided into two classes: first, those which do not form chyme; and, second, those which are capable of being either wholly or partially converted into this substance. To the first class may be referred pure water, alcohol sufficiently diluted to be considered as a drink, and the vegetable acids, &c. When water is received into the stomach, its temperature soon becomes equalized with that of the surrounding viscera; and, at the same time, it becomes mixed with the mucus, saliva, and gastric juice which are found in this organ, by which it becomes turbid, and soon disappears, without undergoing any perceptible change; it partly passes into the small intestines, and is, in part, directly absorbed. After its disappearance, there remains a certain quantity of mucus, which is soon reduced into chyme. We know, from observation, that water deprived of atmospheric air, as distilled water, or when it is charged with considerable quantities of salts, as well water, remains long in the stomach, producing there a sensation of weight. Alcohol acts in a very different manner. We at first perceive a sensation of

warmth, which it impresses as it passes along the mouth, pharynx, and œsophagus, which it likewise excites in the stomach as soon as it arrives there. The effects of this action are to contract the organ, to irritate the mucous membrane, and augment the secretions of which it is the seat; at the same time, it coagulates all the albuminous parts of the alimentary substances with which it is in contact; and, as the different fluids which are found in the stomach contain a large quantity of this matter, the result is, that in a short time after we have swallowed alcohol, there is in this viscus a large quantity of concreted albumen. The mucus undergoes a modification analogous to that of the albumen; it becomes hard, and forms irregular elastic filaments, which preserve a slight degree of transparency.

In producing these phenomena, the alcohol becomes mixed with the water contained in the saliva and gastric juice; it dissolves, probably, a part of the elements which enter into their composition, so that it must become weakened by remaining in the stomach. Its disappearance is extremely sudden, and its general effects are also very rapid, drunkenness or death following, almost immediately, the introduction of a large quantity of alcohol into the stomach. The substances which have been coagulated by the action of the alcohol are, after its disappearance, digested like solid aliments.

Among the drinks which are reduced into chyme, some are only changed in part, while others are entirely transformed into this substance; oil is an example of this: it is changed, in the pyloric portion of the stomach, into a substance very analogous to that which is obtained after the purification of oils by the sulphuric acid; this substance is evidently the chyme of oil. In consequence of this transformation, oil remains, perhaps, longer than any other fluid in the stomach.

It is well known that milk becomes coagulated shortly after it is swallowed. This coagulum is then a solid aliment, which is digested in the ordinary way. Milk and water can only be considered as a drink. The greater number of drinks which we use are formed of water or alcohol, in which are suspended, or held in solution, the immediate principles of animals and vegetables, as gelatin, albumen, osmazome, sugar, gum, fæcula, and colouring or astringent substances. These drinks contain salts of lime, soda, potash, &c. By the results of many experiments which I have made upon animals, and some observations that I have collected upon man, I have ascertained that there takes place in the stomach a separation of the water or alcohol from those substances which these fluids held in solution. These last remain in the stomach, where they are transformed into chyme, like aliments, while the alcohol or water with which they were united is absorbed, or passes into the small intestines. In a word, they act in the manner we have just described in speaking of water and alcohol. Those salts which are held in solution by the water do not abandon this fluid, but are absorbed with it.

Red wine, for example, becomes turbid soon after it is swallowed, from its mixture with those secretions which are formed by, or carried into the stomach. It soon coagulates the albumen of these fluids, which thus become filled with *flocculi;* afterward its colouring matter, disengaged, perhaps, by the mucus and albumen, is deposited upon the mucous membrane. At any rate, we see a certain quantity in the pylorus; the aqueous and alcoholic parts disappear very suddenly. Soups undergo similar changes: the water which they contain is absorbed, while the gelatin, albumen, fat, and probably the osmazome, remain in the stomach, and are reduced into chyme.

Action of the Small Intestines upon Drinks.

From what has been said, then, it appears that drinks penetrate into the small intestines under two different forms, viz.: first, that of a fluid; second, that of chyme. Except under particular circumstances, the fluids which pass from the stomach into the intestines remain but a very short time there. They do not undergo any other alteration than admixture with the chyme, pancreatic juice, bile, and other secretions of these organs. There is no chyle formed from them, but they are generally absorbed in the duodenum, or commencement of the jejunum, being rarely seen in the ilium, and still more seldom in the large intestines. Indeed, this last circumstance seldom happens except in diseases, during the action of a cathartic.

The chyme which is produced by drinks follows the same course, and seems to undergo the same changes, as that of the aliments. Such are the principal phenomena of the digestion of drinks. We must perceive the propriety of considering them separately from the digestion of solid aliments; but they are not digested separately; this vital operation is often carried on at the same time on both classes of aliments. Drinks seem to favour the digestion of the solid aliments; it is probable that they produce this effect in a variety of ways. They soften and dissolve certain aliments, and aid, in this way, their chymification and their passage through the pylorus. Wine acts in a similar manner, especially on those substances which it is capable of dissolving; it excites, also, by its contact, the mucous membrane of the stomach, causing an increased secretion of the gastric juice. The action of alcohol strongly resembles that of wine, varying chiefly in intensity. The principal effect produced by taking *liqueurs* after dinner is an increased excitement of the stomach.

Liquids, as animal decoctions, milk, &c., are sometimes introduced into the large intestines through the rectum, to sustain the strength and nourish the body. I know of no well-established fact that proves the practicability of accomplishing this point; yet it is by no means improbable. This is an interesting question to solve by experiment. It would be curious to observe what change takes place in the nutritious liquid after it should have remained for some time in the large intestine. We have no satisfactory information on this point.

Remarks upon the Deglutition of Atmospheric Air.

Independently of the faculty of swallowing fluid and solid aliments, many persons are capable of introducing air into the stomach by deglutition. It was long supposed that this faculty was very rare, M. Gosse, of Geneva, being the only person publicly known who possessed this faculty to any considerable degree. I have, however, since ascertained, in a work on this subject, that it is far from being uncommon.* In a hundred students of medicine, I found eight or ten who possessed it. In the same work I have shown that we may divide those persons who are capable of swallowing air into two classes: those who do it with great facility, and those who only succeed after great efforts. When persons of the last description wish to do this, they in the first place expel the air from the chest as far as possible; they then fill the mouth with air so as to distend the cheeks and execute deglutition, bringing the chin towards the chest, and then suddenly drawing it away. The action is similar to that of a person with a sore throat, who swallows with difficulty. With respect to those persons who are incapable of swallowing air, who constitute the great majority of mankind, I may observe that, from experiments upon myself, and a great number of students of medicine, I have found that, with little practice, almost any one can do this without great difficulty; for my own part, I succeeded after trying a few days. If there should be any good reason for believing that swallowing air would be useful as a remedy in disease, there can be little doubt that patients could be easily taught to do it.

In the stomach the air becomes warmed and rarefied, and soon distends the organ. In some persons it excites a sensation of burning heat; in others, it causes a desire to vomit, or even sharp pain. It is probable that its chemical composition becomes altered, but there is nothing positively known on this subject. Its continuance in the stomach is various; generally it returns through the œsophagus, and passes out by the mouth. At other times it traverses the pylorus, spreads through the whole extent of the intestinal canal, and at last passes out *per anum.* In this last instance, it distends the whole abdominal cavity, imitating the disease called *tympanitis.* I have remarked, in certain diseases, that the patients swallowed large quantities of air without appearing to be conscious of it. A young physician, a friend of mine, whose digestion is habitually bad, finds considerable relief from swallowing occasionally a mouthful of air.

Remarks on Regurgitation, Eructation, and Vomiting, &c.

We have already seen that the contraction of the œsophagus prevents the substances contained in the stomach, and compressed by the abdominal walls, from returning into this canal. This,

* Memoir on the Deglutition of Atmospheric Air, read before the Institute.

however, sometimes takes place, when it receives the names at the head of this chapter, according to the extent to which it may be carried. The rejection of all the substances contained in the stomach is not effected with equal facility. Gas escapes more readily than liquids, and the last more easily than solid aliments. Generally speaking, the more the stomach is distended, the more easily are its contents rejected by this organ. When it contains gaseous bodies, these necessarily occupy its superior part, and are, of course, in constant contact with the cardiac orifice of the stomach. On the slightest relaxation of this opening, especially when the stomach is strongly compressed, the gas passes into the œsophagus, and if this tube offer no resistance, it arrives soon at its superior part, and escapes through the pharynx, causing the edges of this opening to vibrate; this is called *eructation*. It is probable that the œsophagus, by moving in an opposite direction to that which is executed in deglutition, assists the discharge of the gas through the pharynx. When a quantity of vapour or fluid accompanies the gas which passes out of the stomach, it is called *cardialgia*, or *heartburn*. But it is not necessary that the air discharged in eructation should come directly from the stomach; those persons who possess the faculty of swallowing air can, after it has been forced through the pharynx, allow it to return. It is thus we may have a voluntary eructation, although generally this does not depend upon the will.

If, instead of gas, fluids, or even small masses of solid food, return from the stomach to the mouth, this phenomenon may be called *regurgitation*. This frequently happens in infants, in whom the stomach is habitually distended by a large quantity of milk. It also frequently happens in persons who have eaten and drank very largely, especially when the stomach is strongly compressed by the contraction of the abdominal muscles, in making efforts to go to stool, for example. Although distention of the stomach is favourable to regurgitation, it is also not rare to meet with individuals who discharge, every morning, one or two mouthfuls of gastric juice mixed with bile. This phenomenon is often preceded by eructations, which evacuate the gas that the stomach also contains.

When this viscus is full, it is not probable that its contraction has much effect in forcing the substances which it contains into the œsophagus; the abdominal walls are the principal agents in producing this. But when the stomach is nearly empty, it is probable that the motion of the pylorus has some agency in forcing the fluids into the œsophagus. This seems the more likely, as the fluids which are then rejected are always, more or less, mixed with the bile, which cannot arrive in the stomach without the action of the duodenum and pyloric portion of the stomach. It will be recollected that the œsophagus contracts with but little energy when the stomach is empty. In most individuals regurgitation is entirely involuntary, and only takes place under particular circumstances; but there are some persons who can

produce this at will, and thus remove from their stomach the solid or fluid substances which it contains. In observing them at the moment when they execute this, we shall see they at first make an inspiration, by which the diaphragm is depressed: they then contract the abdominal muscles, so as to compress the stomach; they often assist this action by pressing strongly with the hands the epigastric region; they remain in this position immovable, when suddenly the fluid or aliment is found to ascend into the mouth. It may be presumed that the time they remain immovable, expecting the appearance of the substances in the mouth, is employed in producing a relaxation of the œsophagus, so that the substances which are enclosed in the stomach may be introduced into it. If the contraction of the stomach has any effect in expelling these substances, it can only be considered in a very remote degree auxiliary to it. This power of voluntary regurgitation which some persons possess is generally considered vomiting. There are some individuals who, after eating, take pleasure in causing the food to return to the mouth, to undergo a second mastication, and afterward swallow it. Indeed, they perfectly resemble, in this respect, that class of herbivorous animals which are said to *ruminate*.

Vomiting resembles the phenomena of which we have just been speaking, inasmuch as it has for its end the expulsion of the substances contained in the stomach by the mouth. It differs, however, from these in some important respects; among others, from its being announced by a peculiar sensation, by the efforts which accompany it, and the fatigue with which it is always attended.

We give the name of *nausea* to that internal sensation which precedes vomiting; it consists in a general weakness, with a sense of uneasiness in the head or in the epigastric region; the lower lip becomes tremulous, and the saliva is copiously poured out into the mouth. To this state succeeds, suddenly and involuntarily, convulsive contractions of the abdominal muscles, and, at the same time, of the diaphragm. The first are not very intense, but those which follow are much more so; at last they come to such a degree that the substances contained in the stomach overcome the resistance of the œsophagus, and are thus forced into the mouth. The same effect is produced frequently; it ceases afterward for a considerable time. I have remarked often that animals, about the time they are vomiting, swallow a considerable quantity of atmospheric air. This air seems destined to favour the pressure that the abdominal muscles exert upon the stomach. It is probable that the same phenomenon takes place in man.

At the moment when the substances are driven from the stomach through the pharynx and mouth, the glottis becomes closed; the veil of the palate is raised, and becomes horizontal, as in deglutition. In the mean while, every time we vomit there is introduced a certain quantity of fluid either into the larynx or nasal

fossæ. It has been long supposed that vomiting depends upon the sudden and convulsive contraction of the stomach; but I have shown, in a series of experiments, that this viscus is almost entirely passive, and that the true agents of vomiting are the diaphragm on one part, and the large muscles of the abdomen on the other. I have even seen it produced, after substituting a pig's bladder for the stomach, which I filled with a coloured fluid.*

In the ordinary state, the diaphragm and abdominal muscles co-operate in vomiting; but they may, however, each produce it separately. For example, an animal continues to vomit, though the diaphragm be rendered immovable, by dividing the diaphragmatic nerves. It also vomits after we have divided, with a bistory, all the abdominal muscles, if the precaution be taken of leaving the *linea alba* and peritoneum untouched. I have never seen the stomach contract itself at the moment of vomiting; I conceive, however, that it is not impossible that the movement of the pylorus is not seen at this instant. This was seen by Haller in two experiments, and it induced that illustrious physiologist to suppose that the contraction of the stomach was the essential cause of vomiting.

Modification of Digestion by Age.

Authors generally represent the digestive organs as inactive during the fœtal state; and that at the period of birth there takes place a sudden development of their powers, in order that they may be prepared to furnish the necessary materials for the nutrition and increase of the body. If, by the term inactive, they mean that the digestive organs of the fœtus do not act upon aliments, there can be no doubt of their correctness; but if they wish to be understood to the full extent of the expression, *i. e.*, that they are *absolutely inactive*, I think they are mistaken. It is very probable that there takes place in the organs of digestion, in the fœtus, an action very analogous to that of digestion. But of this subject we shall have occasion to speak more at large when we come to treat of the functions of the fœtus. The same remarks may be applied to the supposition that the digestive system is not fully *developed* at the period of birth. If we speak of the organs contained within the abdomen, it is evident that they are proportionally more voluminous than at a more advanced age; but if it be asserted that the whole digestive apparatus is not so perfect as it afterward becomes, the remark must be acknowledged to be true, because the organs of prehension, mastication, and excretion of fecal matter are far from possessing, at birth, the degree of perfection which they afterward acquire. We cannot suppose that the energy of the abdominal organs can supply the defects of those of which we have been speaking; this is so far from being the case, that it is necessary that the food of infants should be very delicate and easy of digestion; that which is

* See the details of these experiments, and the Report of the Committee of the Institute, in my Memoir on Vomiting, Paris, 1813.

peculiarly adapted to its organs is the mother's milk; when it is deprived of this we all know how difficult it is to find anything that will supply its place. Instead, therefore, of considering the digestive organs of newborn infants, or even of young children, as endowed with great power, we must consider them as much weaker than at a later period. If the digestive apparatus of children must be considered as, in some respects, less perfect than in the adult, nevertheless there can be nothing more admirably adapted to the general purposes which it is destined to fulfil.

Suction is the mode of prehension suitable to infants, and the parts which perform this are peculiarly fitted for the purpose. The tongue is large, in comparison with the whole volume of the body; the absence of the teeth allows the lips to be projected forward to a considerable distance, and to embrace, more exactly than can be done by the adult, the *papilla* or *nipple*, from which the milk is extracted. During the first year the infant is entirely destitute of the organs of mastication; the jaws are small, there are no teeth, the lower jaw is not curved, and does not present the same angle as in the adult; the elevator muscles, which are the principal agents in mastication, are inserted very obliquely. A sort of pad, formed chiefly by the gums, supplies the place of the teeth.

Towards the end of the first year, and in the course of the second, the first or milk teeth pass out from the alveolar processes, and garnish the jaws. Their irruption takes place with considerable regularity, in pairs. The two middle incisors of the lower jaw generally first display themselves, then the two superior, and successively, and in the same order, the lateral incisors, canine, and small molares;* though the last do not often appear until the third year. At the age of four years, four new teeth appear; these are the first large molares; they complete the number of twenty-four, which the child preserves until it is seven years of age. At this period the irruption of the second teeth takes place. The first, or milk teeth, then fall out, generally in the order they appeared, and are successively replaced by those teeth which are destined to remain through life. At this time four large *molares* appear, which make twenty-eight teeth. Between the age of twenty and twenty-five, though sometimes much later, four more teeth appear, which are the *sapient teeth*, and the number of thirty-two teeth, proper to man, is then completed. This renewal of the teeth at the age of seven years is necessary, from the increase which the jaws undergo. The milk teeth being small, those which succeed them are larger, and denser in texture; their roots are longer and more numerous, and they are attached more firmly in the alveolar processes—arrangements indispensable to the functions which they are destined to fulfil.

At the same time that the jaws increase in size, they change their form. The inferior jaw is curved, its branches becoming more vertical, its body assumes a horizontal direction, and the an-

* Sometimes the first small molares come out before the canine.

gle is more distinctly marked. When the teeth first pass out from the alveolar processes, and the instrument is entirely new, the incisors have a sharp cutting edge, the canine teeth are pointed, and the face of the molares covered with sharp conical asperities; but in these respects they become somewhat altered with age. The teeth rubbing continually against each other during mastication, or from being in contact with bodies more or less hard, have their form modified by the friction. We may form some idea of the age of a person by his teeth, but it is so rare that the teeth are disposed with perfect regularity, and possess an equal degree of density, that this can only be remotely approximated. Generally, the effect of using the teeth is first visible in the inferior incisors; it is seen afterward in the molares, but much later in the teeth of the superior jaw. But the effect of use upon the teeth is by no means the most unfavourable change produced by age. On the approach of old age, they are forced from the alveolar processes by the progress of the ossification of the jaws; they thus become loose, and at last fall out. The manner in which this takes place is not regular, as happens in the first teeth, but varies in individuals.

Those who do not lose their teeth until the period of which we are speaking, must be considered as privileged persons; for, generally speaking, they fall out much earlier, either by accidents, such as blows or falls, which fracture or tear them out; or in consequence of the contact of air, or those substances which are habitually introduced into the mouth, by which their texture becomes altered; they exhibit spots, change their colour, become softened, and at last fall into fragments. These alterations are, improperly enough, called *diseases of the teeth;* it is evident, however, that they are chemical changes, as artificial teeth are found to undergo the same process. After the teeth have fallen out, the gums become harder, and the alveolar cavities closed up; an arrangement which, in some sort, supplies the deficiency of the teeth.

Such are the modifications which the organs of mastication undergo with the progress of age; those which take place in the other digestive organs are not of sufficient importance to require being particularized. We shall finish this article by remarking, that those voluntary muscles which assist in digestion undergo, in consequence of age, the same changes which we have already pointed out in speaking of the modifications produced by this cause in muscular contractions.

Our knowledge respecting the modifications of digestion in different ages is very limited; our information on this subject is chiefly confined to the prehension and mastication of aliments, and the excretion of fecal matter; the changes which those parts of the digestive organs which are contained in the abdomen undergo are nearly unknown. Hunger seems to be a very acute sensation in children, and does not return periodically, as in adults; it returns so often that it seems to be continual, and it frequently

appears to exist when the stomach is far from being empty. Suction is a mode of prehension peculiar to infants, and it is readily executed by them, from the extent of their lips and tongue. This action, at least for the first month, appears to be entirely instinctive. Until the appearance of the teeth, and even after dentition has begun, mastication is impracticable. If the infant compress those substances which are placed in its mouth, it is rather to extract the juice which they contain, or to favour their solution, than an attempt at mastication. It may, perhaps, be, that the large quantity of saliva in infants supersedes, to a certain degree, the necessity of mastication.

It is necessary to pass to a consideration of the excretion of fecal matter, in order to be able to say anything positive concerning the digestion of young infants, when compared with that of man at the adult age. The excretions of infants are much more frequent than at a more advanced age; they are almost always quite fluid, of a yellowish colour, and do not possess the peculiar odour which they afterward assume, when other aliments than milk are eaten. The abdominal muscles, probably, do not possess sufficient energy at this age to expel solid fecal matter.

The appearance of the incisor, and even of the canine teeth, are of but little assistance to the infant in the function of mastication. It is necessary that the irruption of the molares should take place, in order that the action should be efficient; even after this has occurred, they cannot be exerted upon substances which offer any considerable degree of resistance, because the elevator muscles of the lower jaw are too weak, and are inserted too obliquely, to allow the teeth to act with much power upon substances possessing a considerable degree of density. It is not until the second dentition, and even some time after, when the angle of the jaw has become well marked, that mastication acquires all the perfection of which it is susceptible. It remains in this state, unless modified by use, or the accidental loss of the teeth, until old age. At this period of life it is generally found that nearly all of the teeth have fallen out, and the person then masticates with the alveolar edge of the jaw. To these causes, which render mastication difficult in old age, may be added, first, the great extent of the lips, which, as soon as the teeth have fallen out, are longer than is necessary to extend from one jaw to another, and which, therefore, touching by their internal surfaces, instead of having their edges in contact, are incapable of retaining the saliva. Second, the diminution of the angle of the jaw, which in this respect resembles that of infants; and the curvature of the body of this bone, which compels old men to chew with the anterior and middle part of the alveolar edge, the only parts where these edges meet. Third, the absence of the teeth induces a necessity of chewing with the lips in contact, which gives, therefore, a peculiar character to the mastication of persons in this situation.

The action of the muscles which concur in digestion undergo the same changes, as we have already pointed out in speaking of

the influence of different ages upon muscular contraction. Feeble in the infant, active and vigorous in youth and manhood, the muscles lose their energy in old age. The digestive actions, which depend upon muscular contraction, run the same round, as any one may satisfy himself by examining the manner in which the prehension, mastication, and excretion of fecal matter take place at the different periods of life. Some old persons are habitually constipated, in consequence of the debility of the muscles. It has sometimes happened that persons have been absolutely incapable of expelling the excrement, in consequence of which it has become accumulated in the large intestine to an enormous extent, so that it becomes necessary to have recourse to a surgical operation.

We know, but in a very general way, the modifications which the stomach and intestines undergo at the different periods of life. They appear to be more active during the increase of the body, and afterward to become more sluggish in their action. But, of all the vital actions, these preserve, until the last moments of life, the greatest degree of energy. We shall not enter here upon the consideration of the modifications which arise in this function from sex, climate, habits, temperament, or the constitution of the individual. These considerations are no doubt interesting, but they more particularly belong to *hygeine;* we shall therefore limit ourselves to observing, that digestion varies in almost every individual, and that, even in the same person, it is rare that digestion does not undergo some change daily, so that a person may digest a substance to-day, and yet be absolutely incapable of doing this on a similar substance to-morrow.

Connexion of Digestion with the Functions of Relation.

A function so important as digestion, and for the performance of which so many different organs co-operate, must necessarily be intimately connected with the other functions, especially those of relation. This connexion exists, indeed it is even so intimate, that in most animals a knowledge of one or more of the organs of external life enables us to form a correct judgment of the disposition of the digestive organs; and, on the contrary, by inspecting one part of the digestive apparatus, we can form a very just idea of the arrangement of the organs of sense and voluntary motion.

The senses point out to us the presence of aliments; they assist us in seizing them, make us acquainted with their physical and chemical properties, and their beneficial or injurious qualities. As it is especially in this last respect that it is of importance for us to appreciate aliments, we may consider the senses of smell and taste, which perform this office, as having more intimate relations with digestion than the other senses; some authors, indeed, have classed them among the digestive actions.

It is often the case that the aspect and odour of food excite the appetite, and prepare the organs of digestion for the discharge of their office. The reverse, however, is sometimes the

case, *i. e.*, it entirely removes all desire of food, and produces a sensation of disgust. Generally speaking, a moderate appetite imparts to the senses more delicacy and activity; but, as we have seen above, when hunger is prolonged, the senses become impaired, so as at last to transmit only imperfect impressions. During chymification, they have also less activity, especially if the stomach be much distended with food. The relations of muscular contraction with digestion are not less evident. We have already shown that the action of the muscles assists in the prehension, mastication, and deglutition of the aliments, and the excretion of the fecal matter; besides this, they transport the body to procure food; they excite the appetite by their action; and, when their efforts are great, they require an abundant nourishment. In their turn they are influenced by digestion; hunger debilitates them, and impairs their motions; and, on the contrary, when the stomach is full, especially in warm climates, and persons in delicate health, there is great indisposition to motion. But in cold countries, and in robust individuals, the presence of food in the stomach increases their vigour and agility.

We may easily explain the difficulty which is felt in singing or speaking after a generous repast. The volume of the stomach prevents the introduction of air into the chest and the motions of the diaphragm, and thus offers an obstacle to the production of the voice. The relation between the functions of the brain and the organs of digestion is particularly intimate. Hunger forcibly directs the thoughts to the means of obtaining aliment; and, on the other hand, strong mental excitement, violent chagrin, or sudden fright often take away the appetite, and stop the powers of digestion for some days; so that aliment which had been before introduced into the stomach remains without undergoing any alteration. Nothing is more common than to see persons. whose minds are oppressed by gloomy affections, in whom the functions of digestion are completely perverted. Contentment and gayety of spirits, on the other hand, favour digestion; great eaters are seldom subject to mental depression. Every one must have noticed the influence which digestion exerts upon the operations of the mind; many persons are absolutely incapable of making any mental effort during digestion; the accumulation of fecal matter in the large intestines has a still more marked influence upon the moral affections.

It has been said that digestion is immediately under the influence of the cerebrum, and that, if the cerebrum was removed, digestion would cease. But I have not found this to be the case; on the contrary, I have seen that digestion continued after nearly the whole cerebrum had been removed. Ducks, in which I had removed the cerebrum and a considerable portion of the cerebellum, survived for eight or ten days, during which their digestion went on very well. They had lost, however, the instinct of hunger, and were capable of executing deglutition but imperfectly. Wounds of the medulla oblongata, and the medulla spinalis, im-

pair digestion much more. But as they, at the same time, affect the respiration and circulation, it is not probable that they influence directly the digestion, but only indirectly through the medium of these functions, so indispensable to life.

Influence of the Great Sympathetic on Digestion.

That mysterious organ called by anatomists the great sympathetic has its principal ganglion, and most considerable plexus, behind the stomach and intestines. A great number of its filaments are sent to the digestive organs. It is, then, probable that digestion is influenced by the great sympathetic. But nothing is known positively of the kind of influence that this organ exerts over this function. We have suppositions, hypotheses, opinions, on this subject; but this is all that is contained in the books on this, one of the most interesting questions in physiology.*

I made a few experiments to ascertain if the filaments of the great sympathetic imparted sensibility to the stomach. I divided both of the eighth pair of nerves above the diaphragm, after which I gave a few grains of tartar emetic. In a short time vomiting took place. This could not depend upon absorption, as the vomiting took place in about five minutes after it was taken. It appears probable that the great sympathetic in this instance transmitted to the brain the impression produced by the antimony on the mucous membrane of the stomach.

The intestines sometimes, when in a state of disease, are endued with exquisite sensibility, and cause excruciating pain. As they do not receive, if we may so express ourselves, cerebral nerves, the sensibility is probably attributable to the great sympathetic. But there is no direct proof of this; it still remains to be settled by conclusive experiments.

CHAPTER XIV.

ABSORPTION AND COURSE OF THE CHYLE AND LYMPH.

It would be useless for the digestive organs to form chyle, if this fluid afterward remained in the intestinal canal. It is, therefore, necessary that the chyle should be transported from the small intestines into the venous system. This is the end of the function which we are now about to examine. To preserve, as far as possible, the method by which we have thus far been gui-

* I would wish to make an honourable exception to this remark in favour of the admirable work of M. Lobstein. But the merit of that important production stops at the anatomical part The physiology is confined to a collection of opinions instead of facts and experiments.

ded in the exposition of the functions, we shall first speak generally of the chyle.

Of the Chyle.

We may consider the chyle in two different points of view. First, when it is mixed with the chyme in the small intestines, and when its characters are such as we have described in speaking of the phenomena of its formation. Second, under the form of a fluid, moving in the chyliferous vessels and thoracic duct. No one having particularly investigated the properties of the chyle during the time it remains in the small intestines, our knowledge on this point does not extend beyond what has been already said on this subject in speaking of the action of this intestine in digestion. On the other hand, the fluid chyle contained in the chyliferous vessels has been examined with great care.

The best method of procuring this fluid is to give food to an animal, and, when a sufficient time has elapsed for the digestion to be going on in its fullest activity, to either strangle the animal, or to divide the spinal marrow behind the occipital bone. We must then lay open the chest through its whole extent, and pass a ligature, which shall embrace the aorta, œsophagus, and thoracic duct, as near as possible to the neck. By turning back the ribs on the left side, we shall then see the thoracic duct, lying alongside of the œsophagus; we then detach this at its upper part, wiping it carefully to remove the blood, and, by puncturing the duct, we may permit the chyle to run into the vessel which is intended to receive it. In this way we shall obtain but a very small quantity; but by occasionally pressing the different parts of the alimentary canal and chyliferous system, it will sometimes continue to ooze out for a quarter of an hour.

The ancients were acquainted with the existence of the chyle, but entertained very incorrect ideas concerning it. At the beginning of the seventeenth century considerable attention was directed to this subject. It was found to be of a white colour and opaque, and was therefore compared to milk, and the vessels which contained it were called *lacteals;* a very incorrect name, inasmuch as there is no resemblance between the chyle and milk, except in colour. It is only of late, and chiefly by the labours of Dupuytren, Vauquelin, Emmert, and Marcet, that we have acquired positive ideas of the chyle. We shall state the observations of these distinguished men, adding those which we have made ourselves.

If the animal from which the chyle is extracted had eaten of fatty animal or vegetable substances, the fluid drawn from the thoracic duct will be of a white, milky appearance, rather heavier than distilled water, of a spermatic odour, stimulating the tongue, a little saltish, and perceptibly alkaline. Soon after having passed out from the vessel in which it was lodged, the chyle runs into a mass, and acquires a consistence almost solid; after some time it separates into three parts: one solid, which is found at the bot-

tom of the vessel; another fluid, which is found above it; and a third, which forms a sort of pellicle on the surface of the fluid; the chyle, at the same time, assumes a bright reddish tint. When it consists of aliments which do not contain fat, its general properties are the same; but, instead of being white and opaque, it is semi-transparent, and the pellicle formed on the surface is less distinctly marked than in the first kind of chyle. The chyle never assumes the colour of those colouring substances which are mixed with the aliments, as some authors have asserted. M. Halle ascertained this by direct experiments. I have recently repeated these experiments, with precisely the same results. After causing animals to eat indigo, saffron, and madder, I have inspected the chyle, but never found that its colour seemed to have any relation to these substances. New experiments have been made on this subject by Tiedemann and Gmelin in Germany, Andrews in Edinburgh, and Lawrence and Coates in the United States, by all of whom these results have been confirmed.

Of the three parts into which the chyle separates when left to itself, that on the surface, of an opaque, white colour, is a fatty substance; the coagulated, or solid part, is formed of fibrine and a little red colouring matter; the fluid is analogous to the serum of the blood. The proportion of these three parts varies according to the nature of the aliments. There are various chyles; for example, that of sugar, which contains but very little fibrine; and that of flesh, which contains much more. The same remark applies to the fatty part, which is extremely abundant when the aliments contain fat or oil, while this is hardly distinguishable when the aliments are destitute of fat. Messrs. Prévost and Dumas have observed in the chyle of the rabbit, dog, and hedgehog minute globules very analogous to those observed in the blood. The same salts which are found in the blood exist also in the chyle. We shall give some farther details relative to the chyle hereafter.

Of the Apparatus of Absorption and the Course of the Chyle.

This apparatus is composed, first, of those absorbent vessels peculiar to the small intestines, which are called the lacteals; second, the mesenteric glands; third, the thoracic duct.

The *lacteal vessels* are extremely small, and very numerous. They arise from imperceptible orifices on the surface of the villosities of the mucous membrane of the intestine, and extend to the mesenteric glands, in the substance of which they seem to be lost. In the walls and on the surface of the small intestines they are extremely delicate and numerous. They inosculate freely, so as to form a fine and beautiful reticulated structure, an arrangement which is especially visible when they are filled with white and opaque chyle. They enlarge in size and diminish in number as they go from the surface of the intestine, and at last form insulated trunks, which extend to the neighbourhood of the mesenteric arteries, and sometimes in the intervals which separate

them; it is, in fact, in this form that they reach the mesenteric glands.

We give the name of *mesenteric glands* to the small, irregularly-formed lenticular bodies which are found before the vertebra column, between the two laminæ of the peritoneum, called the *mesentery.* Their dimensions vary from two or three lines to an inch; they are very numerous; but little is known of their structure. They receive a large number of blood-vessels, in proportion to their size, and are endued with great sensibility. Their parenchyma is of a pale rose-colour, and their consistence not very great. On compressing them between the fingers we extract a transparent, inodorous fluid, which has never been chemically examined. It is especially abundant in the centre of these bodies. I have observed a remarkable quantity of it in the bodies of criminals. The sanguineous and lacteal vessels found in these glands are reduced into tubes of extreme tenuity, so that we are unable to trace the precise relation they bear to each other. It is, however, certain that injections forced into either traverse the gland with the greatest facility. There arise from the mesenteric glands a great number of vessels of the same nature as the lacteals, but in general larger. These are the roots of the thoracic duct. They are directed towards the vertebral column, and run along with the *aorta* and *vena cava.* They anastomose frequently, and terminate in the *thoracic duct.*

The name *thoracic duct* is given to a vessel of the same kind as those which we have just described. It is about the size of a goose-quill, and reaches from the cavity of the abdomen, where it commences, to the left subclavian vein, where it terminates. In its course it passes between the pillars of the diaphragm by the side of the aorta; it then runs along the vertebral column until it arrives opposite to the left subclavian vein, when it turns off and terminates in that vessel. It sometimes opens into both subclavian veins, and sometimes into the right alone. In the interior of the thoracic duct and lacteal vessels are found valves, so arranged as to permit the chyle to pass towards the left subclavian vein, but to prevent its moving in an opposite direction; true valves, however, are not always found. The walls of the lacteal vessels and thoracic duct are composed of two distinct membranes: the one internal, thin, and formed into folds, which constitutes the valves; the external coat is fibrous, and possessed of a greater power of resistance than would have been anticipated from its great tenuity.

Before explaining the phenomena of absorption, and the course of the chyle, it will be proper to make a few observations on the organs which contain it. After twelve, twenty-four, or even thirty-six hours of abstinence, the lacteal vessels of a dog will be found to contain a small quantity of semi-transparent fluid, of a slight milky tint, and which exhibits other properties analogous to those of the chyle. . This fluid, which is met with in the lacteal vessels and thoracic duct, and which has never been analyzed,

appears to be chyle, formed from the digestion of the saliva and mucus of the stomach. This seems the more probable, as the causes which increase the secretion of these fluids, as acid drinks, diluted alcohol, &c., increase its quantity. When the animal is deprived of nourishment for three or four days, the lacteal vessels get into the same condition as the lymphatics, being sometimes filled with lymph, and at others perfectly empty. From these facts, then, it is evident that the chyle of aliments, which is extracted by the lacteals, is always either mixed with the chyle of digested mucus or with the lymph; the result is the same if we extract the chyle of the thoracic duct, which is constantly filled with lymph, even after eight or more days of abstinence. The substance which has been examined by chemists, under the name of chyle, is far from consisting entirely of the extract of the alimentary substances; it is evident that it constitutes only a given proportion of it.

Absorption of the Chyle.

It cannot be doubted that the chyle passes from the cavity of the small intestines into the lacteal vessels. How, then, it may be inquired, is this effected? It would seem, at a first glance, to be easy to explain so simple a phenomenon. But this is not the case. It has already been remarked, that the situation of the mouths of the lacteal vessels is not known, nor is there anything better known of their mode of action, though many persons have undertaken to explain it. This has sometimes been attributed to the capillary attraction of the orifices of the vessels, and the compression of the chyle upon the walls of the small intestines, &c. Of late it has been attributed to a peculiar sensibility in the mouths of the absorbents, and the organic insensible contractility with which they are supposed to be endued. We can hardly imagine how men of ability can either propose or admit such explanations. For my own part, they appear to be a plain and simple acknowledgment of our ignorance of the nature of this phenomenon. There is one fact relating to this subject which it will not be useless to mention; it is, that absorption continues to go on for a considerable time after death. After having emptied one or more of the lacteal vessels, in an animal recently dead, by compression, we shall again see it, in a short time, filled up anew. We may repeat this experiment several times in succession. I myself have done it after the animal has been dead for two hours.

Everything, then, seems to announce that there is something merely physical in the absorption of the chyle. This idea acquires a great degree of probability from the numerous experiments that have been recently made on the imbibition of the living tissues. In carefully examining the mucous membrane of the intestine at the moment of the absorption of the chyle, we discover that each villosity is white, and swollen by the chyle. It appears like a fine sponge filled with milk. It is sometimes of double the thickness if absorption had not taken place. If pressed gently be-

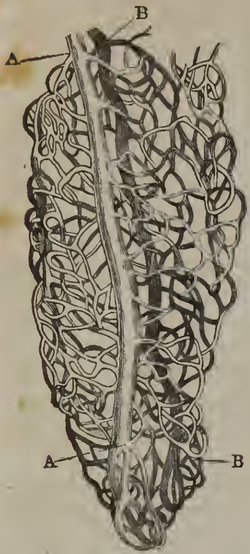
tween the fingers, a small quantity of the chyle will be forced out. If placed in water, and washed about for a time, innumerable small points will appear; they are soft, spongy, and easily torn. These are the first agents in the absorption of the chyle.

The form of these points or villosities varies much in different animals, and even in different individuals of the same species. Perhaps it may be connected with the kind of nourishment. In a dog, in which there was an abundance of very white chyle, there could be seen distinctly, with the naked eye, but much better with a magnifying glass, numerous small orifices. The same papillæ in another animal, a bird, did not present a similar appearance. When examined with a microscope, there could be distinctly perceived very numerous blood-vessels, which lost themselves in a kind of cellular tissue of extreme delicacy. No trace of any other vessels could be observed. A small portion of the internal membrane of the small intestine of a dog of which we spoke was examined with the same microscope. The sanguineous vessels were less numerous; there could be seen merely some white tortuous lines, which commenced near the surface of the papillæ, the small openings of which we have spoken, and which, enlarging as they advanced, terminated in the chyliferous vessels. It would seem probable that these are the origins of this kind of vessels.

If the absorbent vessels of the chyle begin in visible orifices, we can comprehend that the chyle should remain there without entering into the blood-vessels. The chyle, as we have already stated, has globules; now these globules are too large to pass through the porosities of the vascular walls, while there is every facility for their entrance into the openings by which the chyliferous vessels commence. But the chief question will remain, Why do the globules penetrate? and this is precisely what we do not understand.

[It is quite evident that, though the whole mucous membrane of the intestinal canal is capable of absorption, yet that the absorption of the chyle is chiefly accomplished by the *villi.* These are innumerable short processes, from a quarter of a line to a line and a half in length, which impart to the surface of the canal a fleecy or velvet-like appearance. In each villus there is a minute plexus of blood-vessels; the interior of the villus is hollow. In the human subject the villi are cylindrical, but vary in other animals. The following figure represents one of the intestinal villi of a hare, from a dry preparation of Dollinger. It is magnified to about 45 diameters.

(Fig. 34.)
Intestinal Villus of a Hare.



A A are the veins, filled with white injection. B B are the arteries, injected red.

The annexed figure represents the apex of an intestinal villus from the duodenum of the human subject, after Wagner. It is magnified to about 45 diameters.

(Fig. 35.)
Intestinal Villus from the Human Duodenum.

According to Müller, the cylindrical villi of the human subject, when filled with chyle, have a simple cavity running from the base to the apex, this cavity communicating with the lacteal vessels. The next figure represents the appearance of the incipient lacteals in the villi of the jejunum of a young man who had been hung after taking a full meal of farinaceous food. The lacteal that issued from each villosity arose by several smaller branches, in some of which free extremities could be traced, while others anastomosed with each other. Whether this or the simple cavity described by Müller be the ordinary commencement of the lacteals, it is certain that they never open by free orifices on the surface of the intestine, as was formerly imagined. The same is true of the lymphatics which originate in the substance of the various tissues.*

* Carpenter

(Fig. 36.)

Intestinal Villus—Commencement of the Lacteal.

This delineation of a magnified intestinal villus, with the commencement of a lacteal, is after Krause.]

Course of the Chyle.

We have already described the course of the chyle. It at first passes through the lacteal vessels, traverses the mesenteric glands, arrives at the thoracic duct, and is then poured into the left subclavian vein.

The causes which give it motion are, the peculiar contractility of the lacteal vessels, the unknown cause which produces absorption, the pressure of the abdominal muscles, especially in the motions of respiration, and, perhaps, the action of the arteries of the abdomen. If we wish to form a just idea of the rapidity with which the chyle runs along the thoracic duct, it will be only necessary to do, as I have frequently done, viz., to open this canal in a living animal, at the part where it forms a junction with the left subclavian vein. We shall find, then, that its rapidity is not very great, but that it is increased every time the animal compresses the abdominal viscera, by the contraction of the abdominal muscles; we may produce a similar effect by compressing the belly with the hand.

It has always appeared to me that the rapidity with which the chyle circulates through its vessels is proportioned to the quantity which is formed in the small intestines. This depends upon the quantity of chyme; so that if the aliments are abundant, and easy of digestion, the chyle will pass along quickly. If, on the contrary, the aliments are small in quantity, or, what amounts to the same thing, if they are difficult of digestion, as there will be little chyle formed, its progress will be slow. It would be difficult to estimate accurately the quantity of chyle formed during any given digestion; it is no doubt, however, considerable. In a dog of an ordinary size, but who had eaten as much animal food as he chose, from an incision made in the thoracic duct in the neck, the animal being still alive, there passed out more than half an ounce of this fluid in five minutes, and it continued to ooze out as long as the chyle was formed, that is, during several hours.

I do not know if, in the course of the same digestion, the progress of the chyle varies in rapidity; but if we suppose it uniform, it will be perceived that there must enter into the venous system

six ounces of this fluid in one hour. In man, where the chyliferous organs are more voluminous, and where digestion is performed much faster than in the dog, we may presume that the proportion of chyle is much more considerable. The blood which passes through the subclavian vein cannot penetrate into the thoracic duct, because there exists at its orifice a valve so disposed as to prevent this. For the same reason, in consequence of the valves in the thoracic duct and lacteal vessels, the chyle cannot flow back towards the intestinal canal.

Almost all physiologists have supposed that the chyle undergoes some peculiar alteration in traversing the mesenteric glands. Some have suspected that these bodies produce a more intimate admixture of the component parts of the chyle; others have thought that they add to it a fluid intended to render the chyle more liquid: there are others, again, who imagine, on the contrary, that they take away something from the elements of the chyle, in order to purify it. The truth is, we are entirely ignorant of the influence which the mesenteric glands exert upon this fluid. In the same way, much has been said of the variable qualities of this fluid, according as the digestion is good or bad. The decay which takes place in some diseases has been attributed to the formation of a bad chyle, owing to the nature of the aliments. But, indeed, we know very little of the modifications which take place in the composition of the chyle. Much has been said also of certain parts of aliments which pass with the chyle into the blood, without being altered by the digestive organs. But this is mere conjecture, without a single positive experiment to support it.

Dr. Marcet,* who has analyzed the chyle, has compared that formed from animal substances with that of vegetables; he found that the last contained three times as much carbon as the chyle produced from the animal food. We learn from Professor Dupuytren's very ingenious researches, that the thoracic duct is the only route by which the chyle passes, to serve the purposes of nutrition.

We know from the experiments of Duverney, in some cases of obstruction of the thoracic duct; and especially from the experiments of Flandrin, of which we have spoken in another place; I say, we know, on these authorities, that the thoracic duct may cease to pour the chyle into the vein at the point where it terminates, without producing death. We know it is true that in some cases a ligature upon this canal has produced death, though we were then ignorant of the causes of these different results; but the experiments of M. Dupuytren have given a satisfactory explanation of them. This expert surgeon passed a ligature about the thoracic duct of several horses; some of them died in the course of five or six days, while others preserved every mark of perfect health. In those animals which died from the effects of the ligature, it was always impossible to force any injection from the lower part of

* Annales de Chimie, 1816.

the duct into the subclavian vein; it is very probable, therefore, that the chyle ceased to be poured into the venous system after the application of the ligature. On the contrary, in those animals which survived, he always found it easy to make mercurial injections pass, and even other substances, from the abdominal portion of the duct into the subclavian vein. The matter injected followed the duct into the vicinity of the ligature; there it turned aside, and entered some large lymphatic vessels which opened into the subclavian vein. It is, then, evident that, in these animals, the tying of the thoracic duct had not prevented the chyle from mixing with the venous blood.

Inasmuch as the lacteal vessels absorb the chyle, and carry it into the venous system, it has been assumed that they fulfil the same office for all those substances which are mixed with the aliments, and which, without being digested, pass into the blood. Authors have generally said, for example, that drinks are absorbed with the chyle; but, as they have not shown this to be the case by a single experiment, we may reject the opinion, on this ground alone, as doubtful. I have endeavoured to satisfy my own mind on this point, by direct experiments on living animals, but I have not met with a single instance in which I could detect the drink mixed with the chyle. When a dog is made to swallow a quantity of diluted alcohol, during the digestion of solid aliments, if, in half an hour afterward, the chyle be extracted in the manner I have already pointed out, it will be found that this fluid does not contain alcohol, while the blood smells strongly of it, and when distilled, gives over this substance. We obtain similar results by giving a solution of camphor, or any other odorous fluid.

The modifications which take place in the absorption and course of the chyle, in different ages, has never been investigated; we only know that the mesenteric glands change their colour, diminish in volume, and are at last nearly obliterated, in old age. Some authors have supposed that they do not suffer the chyle to pass through them; but this seems to be a mere bold assertion, unsupported by any well-authenticated facts. We are also completely ignorant how far sex, temperament, and habits modify this function; nor are we better informed respecting the relations which exist between this function and those which we have already explained, or which remain for us to examine.*

ABSORPTION OF THE LYMPH.

We have just seen how much remains to be done, in order to give precision to our ideas of the absorption and course of the chyle; but *the function*, a history of which we are now about to give, is still more imperfectly understood. We know generally that it exists, but we have scarcely a remote conception of its utility in the animal economy. Its apparent object is to pour the

* All anatomists, from Hewson and Munroe, have admitted that birds, reptiles, and fishes have a chyliferous apparatus. But no one that I know of has spoken of the chyle of those animals. Chemists and physiologists who have made experiments on the chyme of birds, for example, say nothing of the chyle. If I refer to my dissections, the mammiferi and some reptiles alone have a chyliferous system.

lymph into the venous system. It may be presumed that this phenomenon constitutes but one point in its utility; nevertheless, when we come to define the limits of our knowledge, it is confined to this alone.

Of the Lymph.

Nothing shows more strikingly the imperfection of our knowledge of this function than the different opinions which have been entertained by physiologists of the nature of the lymph. Some have given this name to the serum of the blood, others to the fluid which is seen on the serous membranes, and others, again, to the serosity of the cellular tissue, while some have considered the fluid which oozes from certain scrofulous ulcers as lymph. For ourselves, we intend to confine the meaning of the term lymph to the fluid which is contained in the lymphatic vessels and thoracic duct. It is the more necessary to attach a fixed meaning to this word, because, by admitting other significations, we consecrate as true opinions than which nothing is farther from being demonstrated; namely, that the fluids of the serous membranes, cellular tissue, &c., are absorbed by the lymphatic vessels, and transported by these vessels into the venous system.

To procure lymph, we may have recourse to two processes. The one consists in laying bare a lymphatic vessel, puncturing it, and collecting the fluid which passes out. But this operation is difficult to execute, as the lymphatic vessels are not always filled with lymph. The other process consists in suffering an animal to fast during four or five days, and then to extract the fluid contained in the thoracic duct, in the manner we have mentioned in speaking of the chyle. The fluid which is obtained by either of these methods is of a reddish colour, and opaque. It has a distinct spermatic odour, a saline taste, and sometimes exhibits a decidedly yellowish tint, while at others it is of the colour of madder. I think it important to insist on these details, because a neglect of them has probably induced errors in the experiments which have been made upon the absorption of colouring matter. But the lymph does not remain long in a fluid state; it soon forms itself into a mass; its red colour assumes a deeper tint, numerous reddish filaments become developed in an irregular, arborescent form, very analogous to the vessels found in the tissue of the organs. When we examine with care this mass of coagulated lymph, we perceive that it is formed of two parts; the one of which is solid, consisting of numerous cells, containing the other part, which is fluid; if we separate the fluid part, it again runs into a mass.

Examined by the microscope, the lymph, whether extracted from the thoracic duct, a lymphatic vessel, or a cervical gland, presents a multitude of small globules, similar to those of the blood, but less abundant than in that fluid.—(See *Globules of the Blood.*)

The quantity of lymph which can be collected in this manner from a single animal is very inconsiderable; we can obtain from

a large-sized dog scarcely an ounce and a half. It has appeared to me that the quantity increased as the fast is prolonged. I think, also, that I have observed that its colour becomes redder when the animal has been long deprived of food. The solid part of the lymph, which may be called its coagulum, has a great analogy with that of the blood. It becomes of a scarlet red when it is brought in contact with oxygen gas, and of a purplish red when it is plunged into carbonic acid gas. Its specific gravity, when compared with distilled water, is : : 1022.28 : 1000.00. I requested M. Chevreul to analyze the lymph of a dog. I gave to him a considerable quantity, which I had procured in the manner mentioned above, after having caused the animal to fast for several days. The following are the results obtained by this distinguished chemist. A thousand parts of lymph contained,

Water	926.4
Fibrine	004.2
Albumen	061.0
Muriate of soda	006.1
Carbonate of soda	001.8
Phosphate of lime and magnesia, Carbonate of lime	000.5
Total	1000.0

Apparatus of Absorption, and Course of the Lymph.

There is a strong analogy in the disposition and structure of this apparatus, and that for the absorption and course of the chyle; or rather, except in an anatomical point of view, they form parts of the same system. This apparatus is composed of lymphatic vessels, glands, or lymphatic ganglions, and the thoracic duct, which we have already mentioned in speaking of the course of the chyle. The lymphatic vessels exist in almost every part of the body. They are small, anastomose frequently, and have the same reticulated arrangement everywhere. In the extremities they form two planes, the one superficial, and the other profound. The first is placed in the cellular tissue, between the skin and the aponeurosis beneath; in general, it accompanies the subcutaneous veins. When the vessels which form this plane are filled with mercury, and the injection has succeeded well, they represent a network, which surrounds with its meshes the whole of the limb. The deep-seated lymphatics of the limb are seen principally in the intervals between the muscles, and about the nerves and large vessels.

Both the superficial and deep-seated lymphatics, as they pass towards the superior part of the limb, diminish in number, increase in size, and terminate soon in the lymphatic glands of the groin, armpits, and anus, &c., from whence they pass either into the abdomen or chest. In the trunk, the lymphatics form, in the same manner, two laminæ, the one subcutaneous, the other placed on the internal surface of the walls of the visceral cavities.

Each viscus has also two orders of lymphatics, the one occupying the surface, and the other appearing to arise from the substance of the organ. It has been in vain attempted to trace these vessels in the brain, spinal marrow, and their envelopes, the eye, and the internal ear, &c. The lymphatic vessels of the trunk and extremities accompany the thoracic duct; but those from the external parts of the head and neck terminate in the following manner, viz., those of the right side in a large vessel which opens into the right subclavian vein, and those of the left side into a similar vessel somewhat smaller, which opens into the left subclavian vein, a little above where the thoracic duct discharges itself.

We are ignorant of the disposition of the lymphatic vessels at their origin. Many conjectures have been made on this subject, all equally destitute of foundation. That which seems to be the most plausible is, that they arise by extremely fine roots from the substance of the membranes and cellular tissue, and the parenchyma of the viscera, where they appear to be continued to the last ramifications of the arteries. It often happens that an injection forced into an artery passes into the lymphatics of the part to which it is distributed.

In their course, the lymphatics exhibit no regularity; they increase or diminish in volume; they are sometimes rounded or cylindrical; and sometimes they present a number of swellings near to each other. Their structure does not sensibly differ from the lacteal vessels; like them, they are garnished with valves. In man, each lymphatic vessel, before arriving at the venous system, must traverse a lymphatic gland. But this disposition does not exist in any other animals which have lymphatic glands. These organs are very numerous, and, in form and structure, entirely resemble the mesenteric glands; they are found particularly in the armpits, neck, about the lower jaw, beneath the skin of the nape of the neck, in the groin, and in the pelvis about the large vessels. The lymphatic vessels seem to bear the same relation to them as the lacteal vessels do to the glands of the mesentery.

Functions of the Lymphatic System.

In order that we may investigate with advantage the absorption of the lymph, it is indispensable to examine the ideas which are at present received respecting the origin of this fluid, and the absorbing faculty attributed to the radicals of the lymphatic vessels. It will be necessary for us, in doing this, to make use of great caution, and even sometimes of severity; for, independently of the peculiar difficulty of the subject, we shall have to discuss an opinion generally admitted to be true, and sustained by the most respectable authorities. But as the only motive which animates us is a love of truth, not a fondness for innovation, we trust that no one will feel disposed to censure us for the part we shall take in this question.

Let us inquire, at first, respecting the supposed origin of the lymph. According to the best authors, the lymph is the result of the absorption which the lymphatic vessels exert on the surface of the mucous, serous, and synovial membranes, the laminæ of the cellular tissue, the skin, and the parenchyma of each organ.

The above view comprehends two distinct ideas, viz.: first, that the lymph exists in the different cavities of the body; and, second, that the lymphatic vessels possess the faculty of absorbing it. Of these two ideas, the first is entirely incorrect, and the other deserves a particular examination. Indeed, although there is some analogy between the appearance of this fluid and that which is found on the surface of the serous and synovial membranes, cellular tissue, &c., yet we have already shown that the lymph differs from these fluids, both in its physical and chemical characters. And as these different fluids vary among themselves, if we admit this origin of the lymph, it will necessarily consist of different kinds of fluids. Now the lymph has always been found to possess the same sensible qualities in all parts of the body.

It is true that certain physiologists, who delight in subtleties, reply to this, as they pretend, in such a manner as to removo the difficulty. They say that these fluids, at the moment of their absorption, undergo a particular elaboration, which transforms them into lymph. The proof that they give is, that the absorbed fluids differ from the lymph. This reply would have some force if it was proved that the fluids are absorbed. Now we shall see that we are far from having arrived at this result.

Let us next examine the faculty of absorption, which is attributed by authors to the lymphatic vessels. The fluids introduced into the stomach and intestines are promptly absorbed; the same thing happens in whatever part of the body the fluid is thrown. The skin and the mucous membrane of the lungs possess also the same property. The ancients remarked many of these phenomena, but, being ignorant of the existence of the lymphatic vessels, supposed that the veins were the agents of absorption. This opinion was maintained until the middle of the last century, when the nature of the lymphatic vessels became better understood. William Hunter, one of the anatomists who have contributed most to our knowledge of these vessels, insisted most strongly on their exclusive power of absorption. This doctrine was propagated, and even enlarged upon, by his brother and pupils, and generally by all those who have devoted themselves to the anatomy of the lymphatic vessels. It is necessary that the proofs upon which they founded their doctrine should possess all the strength which they have attributed to them. In consequence of the importance of the subject, we propose entering into some details.

To establish that the lymphatic vessels possess the power of absorption, and that the veins are destitute of it, experiments have been made. But even supposing them to be exact, which, as we

shall hereafter see, is far from being the case, they are so few in number that it is truly astonishing that they should ever have been thought sufficient to overthrow a system which had been so long and generally admitted. Of these experiments, some have been made to prove directly that the lymphatic vessels absorb, and others, again, to show that the veins do not possess this power. We shall, for the present, occupy ourselves with the first, and shall examine the second under the article *Absorption of the Veins.*

John Hunter, who was one of the first who positively denied the absorption of the veins, and admitted that of the lymphatics, performed the following experiment, which appeared to him very decisive of the question. He opened the belly of a dog, and emptied a portion of the intestines of the matter which it contained. He then injected warm milk into it, which was retained by means of ligatures. The veins which belonged to this portion of the intestines were emptied of their blood by small punctures made into their trunks. The blood was prevented from going to them by ligatures on the arteries which corresponded to them; in this situation the part was returned into the belly. He allowed it to remain for half an hour, and then drew it out; and having examined it carefully, he found that the veins were nearly as empty as when they were returned into the belly, and that they did not contain any white fluid, while the lacteals were quite full.* The imperfect state of the art of performing physiological experiments at that time is the only apology for this celebrated anatomist, in not having perceived how many important circumstances there were wanting in this experiment, supposing it to be exact, to enable him to draw any consequences from it. Indeed, in order that this experiment should be of any value, it would be necessary to know if the animal was fasting when it was opened, or was then performing the function of digestion; it would have been necessary to have examined the state of the lymphatics at the commencement of the experiment in order to have ascertained whether they were full of chyle; what changes took place in the milk during the time it remained in the intestine; upon what evidence he asserted that the lacteals were filled with milk at the end of the experiment, or whether the fluid which they contained did not rather consist of chyle. This experiment has been repeated at different times by Flandrin, professor in the Veterinary School of Alfort, a man justly celebrated for the accuracy of his experiments on living animals, without any success; that is, without having perceived milk in the lymphatic vessels. I have myself often repeated this experiment, and the results which I have obtained perfectly agree with those of Flandrin, and are, of consequence, opposed to that of Hunter.

Thus the principal experiment of a distinguished author, who is said to have seen other fluids than chyle absorbed by the lym-

* See Cruikshank's Anatomy of the Absorbent Vessels.

phatic vessels, appears to be, if not an illusion, at least so imperfect that no important inference can be drawn from it. The other experiments of John Hunter being still less conclusive than this, I have passed them over in silence. They have been unsuccessfully repeated by Flandrin, nor have I myself been more fortunate in attempting them.*

I have thought it worth while to endeavour to determine whether the lacteal and lymphatic vessels of the intestinal canal absorb any other fluid than that of the chyle. I, in the first place, ascertained that, if a dog be made to swallow four ounces of pure water, or if it be mixed with a certain quantity of alcohol, or of colouring matter, acid, or salt, at the end of about an hour the whole of the fluid will be absorbed from the intestinal canal. It is evident that, if these different fluids were absorbed by the lacteal vessels of the intestines, they would pass through the thoracic duct; if this were the case, we should find a considerable quantity of them in this duct when we collect the lymph of these animals a half or three quarters of an hour after introducing these fluids into the stomach.

Experiment First. A dog was made to swallow four ounces of a decoction of rhubarb; in half an hour afterward the lymph was extracted from the thoracic duct. This fluid did not present any trace of the rhubarb, although nearly half of the decoction had disappeared from the intestinal canal; the urine, however, perceptibly contained rhubarb.

Experiment Second. A dog was compelled to drink six ounces of a solution of the prussiate of potash in water; a quarter of an hour afterward the urine was found evidently to contain the prussiate; the lymph extracted at the same time from the thoracic duct manifested no signs of it.

Experiment Third. Three ounces of alcohol diluted with water were given to a dog.† At the end of a quarter of an hour the blood of the animal exhibited a marked alcoholic odour; but in the lymph nothing of the kind was found.

Experiment Fourth. Having passed a ligature about the thoracic duct of a dog near the neck, he was made to drink two ounces of a decoction of *nux vomica*, a liquid which is extremely poisonous to animals; the animal died as suddenly as if the thoracic duct had been left perfect. On opening the body it was ascertained that the duct was not double, but that it terminated singly in the left subclavian vein, and that the ligature had been tightly drawn around it.

Experiment Fifth. A ligature was passed about the thoracic duct of a dog, and two ounces of a decoction of nux vomica injected into the rectum. The effects were similar to those which would have taken place if the duct had not been tied, *i. e.*, the animal died almost immediately. The structure of the duct was analogous to that in the preceding experiment.

* John Hunter employed but five animals in all his experiments upon absorption.
† Pure alcohol kills dogs almost immediately.

Experiment Sixth. M. Delille and myself performed the following experiment upon a dog, which, seven hours before, had been allowed to eat a large quantity of food in order that the lacteal vessels might be easily perceived. We made an incision into the abdominal walls, and drew out a fold of the small intestines, upon which we applied two ligatures sixteen inches apart. The lacteals which arose from this portion of the intestine were extremely white and distinct in consequence of the chyle with which they were distended. Two new ligatures were placed upon each of these vessels about four inches apart; and we then divided these vessels between the two ligatures. We satisfied ourselves also, by every possible means, that the fold of the intestines taken from the abdomen had no communication with the rest of the body by lymphatic vessels. Five mesenteric arteries and veins were sent to this portion of the intestine. Four of these arteries, and the same number of veins, were tied and divided in the same manner that the lymphatics had been; afterward the two extremities of this fold of intestine were divided, and entirely separated from the rest of the small intestines. Thus we had a portion of small intestine, about sixteen inches long, not communicating with the rest of the body except by one mesenteric artery and vein. These two vessels were insulated about four fingers' breadth in length. We removed even the cellular coat, lest lymphatics should be concealed in it. We then injected into this fold of intestine about two ounces of the decoction of the nux vomica, a ligature being applied to prevent the passing out of the injected fluid. The fold was then covered with a piece of fine linen, and replaced in the abdomen. In the space of an hour, or an hour and six minutes, the effects of the poison were manifested with their ordinary intensity, so that everything took place as if the fold of intestine had been in its natural state.

Dr. Segalas has made some opposing experiments; I transcribe literally the following facts from his memoir:

"*Experiment First.* I took a fold of intestine that I isolated from the neighbouring parts by two incisions. I tied the arteries and veins that were distributed there, taking care not to include in my ligatures the chyliferous vessels rendered apparent by the presence of chyle. I applied a ligature to one extremity of the fold of intestine. I then injected into its cavity the poison which I had already used, an aqueous solution of the alcoholic extract of the nux vomica. I confined it to this cavity by a second ligature. I then replaced the fold of intestine in the belly, but no poisoning took place during a whole hour that I observed the animal. I used half a drachm of the extract, carefully prepared by M. Laborraque, and tested by many previous experiments, in which a few grains of this substance had been found sufficient to kill dogs, the animals on which I experimented.

"To this experiment it may be objected that the circulation being stopped in a fold of intestine, the absorption might have been suspended from the mere deficiency of the excitation of the blood;

and, consequently, that the *non*-poisoning in this case did not prove the *non*-absorption in the normal state by the chyliferous vessels.

"Without stopping to examine here the influence of the circulation over absorption, an influence that one cannot justly appreciate without first determining what are the true agents of absorption, I shall limit myself to observing that the partisans of absorption by the lymphatic vessels cite many analogous experiments by John Hunter, and in which this philosopher, after having isolated the fold of intestine, and tied the arteries and veins, detected the passage of a certain quantity of milk, warm water, coloured starch, &c., into the chyliferous vessels. If my experiment is rejected in consequence of the supposed death of the fold of intestine, the experiments of Hunter must share the same fate. Besides, these experiments, which appear to be the most favourable of all to absorption by the lymphatic vessels, are obnoxious to objections. It may be said, for example, that the white fluid seen by Hunter in the chyliferous vessels a quarter of an hour after milk was introduced into the fold of intestine, was only the chyle prepared from this milk, or intestinal mucus deposited previously in the chyliferous radicles.

"*Experiment Second.* To avoid the objection of the death of the intestinal fold, in a second dog I took another intestinal fold, which I isolated from the rest of the digestive tube and the circulatory system, leaving only one large artery to carry blood. The result was the same as in the preceding case: no poisoning took place. But it may be objected that the stasis of the venous blood might have caused a sort of local asphyxia equivalent to death as respects absorption, and that it was not surprising, therefore, that absorption did not take place.

"*Experiment Third.* To reply to this last objection, in a third dog I took a new fold of intestine, that I prepared as in the preceding experiment, with this difference, that I isolated the vein corresponding to the preserved artery, and kept it outwardly, after having detached it from the mesentery with due precaution. By this vein I allowed the superfluous blood to be discharged; but still the poison, when introduced into the intestinal fold, did not act.

"It might be suspected that there was some accidental or individual circumstance that prevented the absorption; to determine this, I made still another experiment.

"*Experiment Fourth.* After having vainly attempted to poison a dog, as in the preceding experiments, waiting a full hour to see the result, I restored the circulation by untying the vein; under these circumstances the poisoning took place in about six minutes.

"These results, which, besides removing the objection against your experiment on the intestinal fold of anastomoses between the venous radicles and the lymphatics, appear to me to prove that intestinal absorption is accomplished exclusively by the veins, at least as respects the substance employed by me."

I have often repeated each of these experiments, and have varied them in different ways, and have always found the same results. I think they are sufficient to show positively that the lymphatic vessels are not the only agents of intestinal absorption, and that they are at least sufficient to render doubtful the opinion that these vessels absorb other substances than chyle. It is rather from analogy than from positive facts that it has been admitted that lymphatic absorption takes place from the genito-urinary and pulmonary mucous surfaces, the serous and synovial membranes, the cellular tissue, the surface of the skin, and the substance of the organs. We intend, nevertheless, to examine the small number of proofs by which they have been supported by authors. The lacteal vessels of the intestinal canal are the only effective organs of absorption in this part; the lymphatic vessels, then, of the rest of the body, which exhibit a similar arrangement to the lacteals, must possess the same power. Such is the reasoning of the partisans of lymphatic absorption; and, as it is known that all the external and internal parts of the animal economy absorb, it has been concluded that the lymphatic vessels were the only instruments of absorption.

If the faculty of lymphatic absorption of other substances than chyle from the intestinal canal had been demonstrated, there would be much force in this reasoning.

But as we have already proved that there is nothing less certain than this, we cannot admit it, and we are obliged to recur to other facts or experiments, which, as is generally believed, demonstrate lymphatic absorption.

In animals which had died in consequence of pulmonary or abdominal hemorrhage, Mascagni found the lymphatics of the lungs and peritoneum filled with blood. He concluded, therefore, that these vessels absorbed the fluid with which they were filled. But I have often met, both in animals and in men, the lymphatics distended with blood where there had been no extravasation of this fluid; besides, in some cases there is so little difference between the lymph and the blood, that it will be difficult to distinguish them. The fact, therefore, of Mascagni has no important bearing on the question.

John Hunter, after having injected water coloured with indigo into the peritoneum of an animal, said that he saw the lymphatics, shortly afterward, filled with a fluid of a blue colour; but this fact has been disproved by the experiments of Flandrin upon horses. This author injected into the pleura and the peritoneum, not only a solution of indigo and water, but other coloured fluids, but he never saw them in the lymphatics, though they were promptly absorbed. M. Dupuytren and myself have made more than a hundred and fifty experiments, in which we have submitted a great number of different fluids to the absorption of the serous membranes, but we have never seen them, in a single instance, introduced into the lymphatic vessels. The substances which were thus introduced into the serous cavities produced very sudden effects, from

the rapidity with which they were absorbed. Opium produced drowsiness, and wine drunkenness, &c. I have satisfied myself, by many experiments, that tying the thoracic duct does not diminish the promptitude with which these effects manifest themselves.

It is very doubtful, then, whether the lymphatic vessels are the organs which absorb in the serous cavities. We may add, that the tunica arachnoides, the membrane of the aqueous humour, and the membrana hyaloidea, the disposition and structure of which are very analogous to the serous membranes, and in which no lymphatic vessels have ever been detected, possess a faculty of absorbing as active as the other membranes of the same kind.

When we apply a ligature upon one of the extremities, that part of the limb which is most distant from the heart swells, and the serosity accumulates in the cellular tissue. An analogous phenomenon sometimes occurs after extirpating cancerous mammæ, in which the operator is obliged to remove all the lymphatic glands from the axilla. This phenomenon has been explained by supposing that the ligatures, or the removal of the glands from the armpit, prevent the circulation of the lymph, and especially the absorption in the cellular tissue. Let us inquire how far this explanation is satisfactory. In the first place, the lymph is a very different fluid from the cellular serosity; again, may not the accumulation of this serosity depend upon other causes than the obstructed action of the lymphatics—for example, the slow circulation of the venous blood? Besides, the removal of the glands from the axilla do not always produce the effect which we have mentioned; and we frequently see scirrhus engorgements, and even a complete disorganization of the glands of the armpit, or groin, which are not accompanied with any œdema.

Numerous proofs are alleged of the absorption of the lymphatic vessels of the skin. It sometimes happens, when a person punctures his finger in dissecting a body in a state of putrefaction, that two or three days afterward the puncture becomes inflamed, and the corresponding glands of the armpit swell, and become painful. In some rare instances these effects are accompanied by a vivid redness, and pain through the whole course of the lymphatic trunks of the arm. Under these circumstances, it is supposed that the putrefied animal matter is absorbed by the lymphatics of the finger, that it is transported by them to the glands of the armpit, and that its passage has been marked by the irritation and inflammation of the parts through which it has passed.

It cannot be denied that this explanation accounts, plausibly enough, for all the appearances, nor shall I pretend to assert that it is not correct; I suspect, even, that its truth may hereafter be demonstrated. But when we reflect that it is at this moment one of the foundations of therapeutics, and that it often happens that powerful remedies are employed on this principle, I think we do not go too far in doubting it. I shall make some reflections upon this explanation. In a great majority of instances, a puncture

from a scalpel impregnated with putrid matter does not produce any injurious effects. It frequently occurs that a puncture with a needle, perfectly clean, produces exactly the same phenomena as those which have been described; a slight blow, by which the end of the finger is contused, leads also to precisely the same effects. The simple impression of cold upon the feet causes frequently a swelling of the glands of the groin, and a redness of the lymphatics of the internal part of the leg and thigh. We may also add, that it is common to see the veins become inflamed in consequence of punctures, and even to concur with the lymphatics. I saw a very striking and unfortunate instance of this in the body of Professor Lecler. This estimable philosopher died in consequence of the absorption of putrid miasmata, from a slight scratch on one of the fingers of the right hand. The lymphatics and the glands of the armpit were inflamed, the glands were of a brown colour, and evidently diseased; but the internal membrane of the veins of the right arm exhibited unequivocal marks of inflammation, and the lymphatic glands of the whole body had undergone the same alteration as those of the right armpit.

There are also many facts in pathology which are alleged as proofs of lymphatic absorption. After an impure coition, an ulcer appears upon the *glans penis;* in the course of a few days, one of the glands of the groin becomes inflamed, swollen, and painful; or one of these glands inflames without any preceding ulceration upon the penis. This not unfrequently occurs during the first few days of a severe gonorrhœa. In these cases, it is supposed that the orifices of the lymphatics absorb the venereal virus, and then transport it to the glands, in consequence of which these parts are thrown into a state of engorgement. As they often return to a healthy state, after the application of mercurial frictions to the internal part of the thigh, it has been concluded that the mercury is absorbed by the lymphatics of the skin, and that it passes through both them and the glands of the groin. These circumstances are sufficient to excite a suspicion of the absorption of the lymphatic vessels, but they certainly do not demonstrate it. This can never be absolutely demonstrated until the substance supposed to have been absorbed is found in these vessels; and as no one has ever seen, in cases of venereal ulcer or gonorrhœa, pus, or when the mercurial unguent has been applied, mercury in the lymphatic vessels or glands, it is evident they cannot be considered as demonstrative evidence of lymphatic absorption. It is a different thing when we meet with pus, or mercurial ointment, or any other substance administered by frictions, in these vessels; we must then satisfy ourselves whether they have penetrated by means of absorption. We shall see hereafter with what facility those substances which are mixed with the blood often pass into the lymphatic system.

Mascagni cites an experiment made upon himself, which he thinks conclusive; I will literally translate it. "Having kept my feet plunged in water for several hours, I observed a somewhat

painful swelling of the inguinal glands, and the transudation of a fluid through the gland. I was seized with a defluxion of the head, and had a constant discharge of a salt and acrid fluid from my nostrils. The following is the explanation which I give of these phenomena. When the lymphatics of the feet were filled with an unusual quantity of fluid, and the inguinal glands became swelled, the lymphatics of the penis were filled with more difficulty. The sanguineous vessels continuing to separate the same quantity of fluid, the lymphatic vessels were insufficient to remove the whole of it, as their action upon the fluid, which they naturally contain, was retarded; this is the reason why the rest of the secreted fluid transuded through the gland. Again: in consequence of the abundant absorption of the lymphatics of the feet, the thoracic duct was distended with great force, and the lymphatics of the pituitary membrane were incapable of absorbing freely the fluids deposited upon their surface; hence the coryza." We learn, from this experiment, that Mascagni had the glands of the groin swelled, after having suffered his feet to remain some time in water; the explanation which follows is merely conjectural.

It is by inference alone that absorption of the lymphatic vessels in the deep-seated organs has been admitted, but it is not maintained by any experiments. The facts which are alleged in proof of it, such as metastasis, the resolution of tumours, the diminution of volume in the organs, &c., establish clearly enough the fact of internal absorption; but they by no means prove that the lymphatic vessels execute it. I will mention a circumstance which, in my opinion, is much more favourable to the doctrine of the absorption of the lymphatic vessels than any which I have yet related. I am indebted to M. Dupuytren for this fact. A woman who had an immense tumour on the superior and internal part of the thigh, with fluctuation, died in the Hôtel Dieu in 1810. A few days before her death an inflammation had taken place in the sub-cutaneous cellular tissue, on the internal part of the tumour. On the following day M. Dupuytren examined the body. He had scarcely divided the skin that covered the tumour before he remarked white points upon the lips of the incision. Surprised at this phenomenon, he carefully dissected the skin to a certain extent, and found white lines, some of which were as large as crow quills, running over the sub-cutaneous cellular tissue. These were evidently lymphatic vessels, filled with puriform matter; the lymphatics were filled with the same fluid as far as the lumbar glands, but neither these glands, nor the thoracic duct, exhibited any trace of it.

It will be asked if this fact is not enough to justify us in concluding that the lymphatics had absorbed the fluid with which they were distended? This is probable; but, in order to render it certain, it would be necessary to prove the identity of the fluid contained in the lymphatics, and that of the pus with which the cellular tissue was filled. We only know this from appearance. M. Cruveilhier, who relates this fact, expresses himself thus: "I

have said that this fluid was pus; it had the opacity, whitish colour, and consistence of pus." Now the simple appearance is so deceitful, that we incur much risk in depending upon it. Under similar circumstances, two fluids essentially different from each other, as milk and chyle, were for a long time confounded, merely because they had the same appearance; besides, we have no evidence that the lymphatics were not inflamed, and furnished the pus themselves, a thing which not unfrequently happens in the veins.

Under many similar circumstances, for example, after erysipelatous inflammation, with suppuration of the cellular tissue of the extremities, I have not been able to distinguish any marks of purulent matter in the lymphatic vessels. Besides, it is not uncommon to find, in cases of this kind, the veins which arise from the diseased part filled with a substance very analogous to pus.

In returning to the consideration of the absorbing power of the lymphatic vessels, we may remark, that it is not impossible that it may exist; but still this is far from being demonstrated; and as we are in possession of a great number of facts which appear to us to establish positively the absorption of the venous radicles, we shall consider the history of the different kinds of absorption when we come to treat of the course of the venous blood.

The knowledge that we have recently acquired of the power of imbibition of living tissues adds new and important considerations to those we have already presented.

A solid or liquid substance capable of being absorbed cannot be imbibed through the walls of the lymphatics so as to reach the interior of these vessels by a mere physical action. But absorption does not consist in such a phenomenon; it is also necessary that the substance which has penetrated into the cavity of these vessels should be transported into the torrent of the circulation. Now the lymphatics are generally empty; they have no current that can carry along the substances they may absorb. This want of current is opposed to regarding the lymphatics as an absorbing system.

We now return to the origin of the lymph, as admitted by physiologists. If, on the one side, the fluids which are supposed to be absorbed by the lymphatic vessels differ from the lymph in their physical and chemical properties; and if, on the other hand, the faculty of absorption in the lymphatic vessels be a phenomenon the existence of which is very doubtful, what can we think of the received opinion of the origin of the lymph? Is it not evident that it has been lightly admitted, and that it has little probability in its favour? From whence, then, does the fluid arise, which we meet in these vessels? or, in other words, what is the most probable origin of the lymph? From the nature of the lymph, which has a great analogy to the blood, from the communication which anatomy demonstrates to exist between the termination of the arteries and the origin of the lymphatics, and from the facility and promptitude with which coloured and saline fluids

are introduced into these vessels,* it appears to me very probable that the lymph is a part of the blood, which, instead of returning to the heart by the veins, follows the route of the lymphatic vessels. This idea is not entirely new; it resembles very much that of those anatomists who first discovered the lymphatic vessels, and who thought that these vessels were destined to carry back a part of the serum of the blood to the heart.

This idea is much more probable when we recollect that the artificial plethora of the sanguineous system augments very much the quantity of lymph in the lymphatic system, as we shall see in the general remarks on the circulation of the blood.

This discussion of the origin of the lymph may appear to some to be too elaborate; but it was indispensable to avoid the false opinions which have been entertained of the absorption of this fluid. It is evident that it is necessary to form a very different idea on this subject from what is found in works on physiology, and to limit ourselves to an investigation of the mode in which the lymph passes into the lymphatic extremities. But with what obscurity is this phenomenon surrounded? We are ignorant of its cause, mechanism, the disposition of the instruments which execute it, and even the circumstances under which it takes place. Indeed, as we have already remarked, it appears that it is only under particular circumstances that the lymphatics contain lymph. There is nothing about this obscurity that should surprise us; we have already seen, and we shall have often occasion hereafter to remark, that it reigns over all the phenomena of life to which we cannot apply the laws of physics, chemistry, or of mechanics; of consequence, over all those functions which relate to vital action and nutrition.

Course of the Lymph.

We have but a few words to say on this subject; authors have scarcely noticed it, though it is still vague, and our own observations on this point will be found far from satisfactory. This is an interesting subject of research, and one entirely new.

From the general arrangement of the lymphatic apparatus, its termination in the thoracic duct, and its cervical trunks, in the subclavian veins, and the form and arrangements of its valves, we cannot doubt that the lymph passes from the different parts of the body, from which the lymphatics arise, towards the venous system. But the particular phenomena of its motion, its causes, variations, &c., have not yet been investigated.

The following remarks are the result of my own examination of this point. 1st. In man and living animals it is very rare that the lymphatics of the extremities, head, and neck, contain lymph; their internal surface alone appears to be lubricated with a very thin fluid. In certain cases, however, the lymph is arrested in one or more of these vessels, distends them, and gives to them an

* I have established this fact by direct experiments, an account of which I shall give below.

appearance very analogous to that of varicose veins, differing only in colour. M. Sœmmering has seen this often on the back of the foot of a female, and I have had occasion to observe a similar instance of it on the corona glandis. We find frequently in dogs, cats, and other living animals, lymphatic vessels full of lymph, on the surface of the liver, gall, bladder, the vena cava of the trunk, the vena portæ, in the pelvis, and on the side of the vertebral column. The cervical trunks are also frequently filled with lymph, though it is by no means rare that they are found entirely empty. With respect to the thoracic duct, I have never seen it empty, even when the lymphatic vessels of the rest of the body were in a state of perfect vacuity.

2d. Why do those varieties exist in regard to the lymph in the lymphatic vessels? why do those of the abdomen contain it more frequently than the rest? and why does the thoracic duct contain it constantly? I acknowledge myself incapable of giving a satisfactory answer to either of these questions. The only circumstance which I think I have observed, but which I will not undertake positively to assert, is, that the lymph is found most frequently in the trunks of the lymphatics of the neck, when animals have been long deprived of every kind of aliment and drink.

3d. As abstinence is prolonged in a dog, the lymph becomes more and more red. I have seen it when its colour was nearly that of blood, in dogs which had fasted eight days. It has appeared to me, also, that in these cases its quantity is more considerable.

4th. The lymph appears to move slowly in the vessels. If we puncture a lymphatic in man during life (I had once occasion to do this), the lymph passes out but slowly, and without a jet. M. Sœmmering had already made a similar experiment. When the lymphatic trunks of the neck are filled with lymph, we may easily insulate them to the extent of an inch. We may then perceive that the fluid which fills them passes along very gently. If we compress them so as to make the lymph, with which they are distended, pass into the subclavian vein, it is often half an hour before they become filled anew, or they remain empty.

5th. Nevertheless, the lymphatic vessels evidently possess a contractile power; they empty themselves frequently as soon as they are exposed to the air. It is probable that, in consequence of this contraction, they are almost always found empty, except the thoracic duct, in animals recently dead. This power is undoubtedly one of the causes which determine the introduction of the lymph into the venous system. The pressure which the lymphatics receive from the contractility of the tissue of the skin and other organs, muscular contraction, the pulsation of the arteries, &c., must have a considerable effect upon the course of the lymph. This is evident in the lymphatics of the abdominal cavity.

6th. We are completely ignorant of the use of the lymphatic

glands; this is, no doubt, the reason why they have been the object of so much speculation. Malpighi considered them as *small hearts*, which gave a progressive motion to the lymph; others have supposed that they served to form divisions in the lymphatic vessels, and to imbibe, like sponges, the superfluous humours, to give a nourishing juice to the nerves, to form fat, &c. In a word, almost every one has given, on this subject, an unbounded freedom to his imagination.*

We shall say no more on the course of the lymph; it may easily be seen how much remains to be done to throw light on this phenomenon, and, generally, upon all those which relate to the functions of the lymphatic system, and its utility in the animal economy. If our actual knowledge of this subject is so limited, with what confidence can we receive those medical hypotheses in which we hear of the thickening of the lymph, the obstruction and imperfect action of the lymphatic glands, and of the defective action of the absorbent mouths of the lymphatics, which are supposed to occasion dropsies? And how shall we determine to administer remedies, often violent, founded on such reasoning? The changes of structure and volume which take place in the lymphatic glands, from age, must induce us to presume that the action of the lymphatic system undergoes modifications in the different periods of life, but there is nothing positively known on the subject.

CHAPTER XV.

COURSE OF THE VENOUS BLOOD.

The object of the function which we are now about to examine is to transport the venous blood from all parts of the body and lungs. The organs which execute it are also the principal agents of absorption on the external and internal parts of the body, with the exception of the absorption of the chyle, the lymph, and that which takes place from the mucous surfaces of the lungs.

Of the Venous Blood.

This name is given to that animal fluid which is contained in the veins, the right side of the heart, and the pulmonary artery; organs which, by their union, form the apparatus appropriated to the venous blood. This fluid is of a brownish-red colour so deep that it has received the name of black blood. In some cases its colour is less deep, so as to be scarlet. Its odour is disagreeable

* I think it unnecessary to notice particularly the retrograde motion of the fluids in the lymphatic vessels; the observations of Darwin and others, upon this subject, I conceive to be merely imaginary.

and *sui generis;* its taste is also peculiar; we perceive, however, that it contains salts, and, principally, the muriate of soda. Its specific gravity is something more than water; Haller found the medium to be, : : 1.0527 : 1.0000. Its capacity for caloric may be expressed by 934, that of the arterial blood being 921; its medium temperature is 101° of Fahrenheit. When viewed with a microscope while moving in the vessels, the venous blood exhibits an infinite number of small globules, the dimensions, form, and structure of which have been examined with great care by Messrs. Prévot and Dumas. The venous blood, when taken from its vessels and left to itself, forms, at the end of a few moments, a soft mass; by degrees this mass separates spontaneously into two parts: the one a yellowish transparent fluid, called the *serum;* the other soft, but nearly solid, of a deep brownish-red colour, which is called the *crassamentum;* the last occupies the lower part of the vessel, the *serum* rising above it. Sometimes there is formed on the surface of the *serum* a thin, soft, and reddish coat, to which the name of *crust of the blood* has been very improperly given. At the moment of coagulation the blood disengages small air bubbles, which, in passing to the surface, hollow out small canals in the coagulum. This phenomenon is much more apparent in a vacuum. This spontaneous separation of the elements of the blood does not occur until it has remained for some time in a state of rest. If it be agitated it remains fluid, and retains for a much longer time its homogeneous appearance.

When venous blood is brought in contact with atmospheric air, or oxygen gas, it assumes a vermilion tint; with ammonia, it becomes of a cherry red; with azote, of a reddish brown, but much deeper colour.* While changing colour, it absorbs a considerable quantity of these different gases. When kept for some time under a receiver, placed over mercury, it exhales a considerable quantity of carbonic acid. M. Vogel has made some researches on this subject.†

The serum is a transparent liquid, slightly yellow, which it owes to a colouring matter; its taste and odour are, like those of the blood, decidedly alkaline. At 70° of the Centigrade thermometer, it assumes the form of an albuminous mass; in coagulating, it forms numerous cells, which contain matter very analogous to mucus. It preserves its property of coagulating into a single mass, even when diluted with a considerable quantity of water. According to Mr. Brande, the serum consists of almost pure liquid albumen, united with soda, which keeps it liquid. Of consequence, anything that removes the soda from it will cause coagulation. By the action of heat, the soda will transform a part of the albumen into mucus. The action of the galvanic pile coagulates the serum and develops globules, which are very analogous to those of the blood.

* For changes in colour, which the venous blood undergoes when brought in contact with the different gases, see vol. iii. of the Chemistry of M. Thenard, p. 513.

† Annals of Chemistry, year 1816.

According to M. Berzelius, one thousand parts of the serum of the human blood contain,

	Water		903.0
	Albumen		80.0
Substances soluble in alcohol.	Lactate of soda and extractive matter	4	
	Muriate of soda and potash	6	10.0
Substances soluble in water.	Soda and animal matter, phosphate of soda	4	
	Loss	3	7.0
	Total		1000.0

M. le Canu, who has recently analyzed the blood, has attributed to the serum a somewhat different composition. He has found two fatty substances, one of which is crystallizable, and the other oily.

Analysis according to M. le Canu.

	1st Analysis.	2d Analysis.
Water	906.00	901.00
Albumen	78.00	81.20
Organic matters soluble in water and alcohol	1.69	2.05
Albumen combined with soda	2.10	2.55
Fatty crystallizable matter	1.20	2.10
Oily matter	1.00	1.30
Chlorine of sodium " of potassium	6.00	5.32
Sub-carbonate Phosphate Sulphate	2.10	2.00
Sub-carbonate of lime " of magnesia Phosphate of lime " of magnesia " of iron	0.91	0.87
Loss	1.00	1.61
Total	1000.00	1000.00

The serum sometimes presents a whitish, milklike appearance, from which it has been supposed that it contains chyle; the substance that gives to it this appearance resembles oil.

The crassamentum of the blood is chiefly formed by the fibrine and colouring matter. When separated from the colouring matter, the fibrine is solid, whitish, insipid, and inodorous; it is heavier than water, does not produce any action upon vegetable colours; it is elastic when it is humid, and becomes brittle by dessication; by distillation, it furnishes a large quantity of the carbonate of ammonia, and a large mass of carbon, the ashes of which contain a considerable quantity of the phosphate of lime, a little of the phos-

phate of magnesia, carbonate of lime, and carbonate of soda. One hundred parts of fibrine are composed of

Carbon	53.360
Oxygen	19.685
Hydrogen	7.021
Azote	19.934
Total	100.000

The colouring matter is soluble in water and the serum of the blood. When examined by a microscope, after being dissolved in these fluids, it appears, like most parts of the fluids in the animal economy, to consist of small globules; when dried, and calcined afterward in contact with the air, it melts, bursts up into bubbles, burns with a flame, and forms a carbon, which cannot be reduced into ashes but with extreme difficulty. This carbon, during its combustion, disengages ammoniacal gas, and furnishes a hundredth part of its weight of ashes. It is composed of

Oxide of iron	55.0
Phosphate of lime and a trace of the phosphate of magnesia	8.0
Pure lime	17.5
Carbonic acid	19.5
Total	100.0

It is important to remark, that there is not found in any part of the blood either gelatin or phosphate of iron, as was formerly believed. The respective proportion between the quantity of the serum and the crassamentum, those of the colouring matter and fibrine, have not been carefully examined, as we shall see hereafter. It is probable that they are varied by an infinite number of circumstances.

M. le Canu, in his valuable work already cited, in twenty two comparative experiments, made on persons differing in age, sex, and temperament, gives the following results:

In 1000 *parts of Blood.*

	Dry Fibrine.	Humid Fibrine.
Maximum	7.233	28.940
Minimum	1.360	5.440

We thus see how the proportion of this element may vary.

The coagulation of the blood has been, in turn, attributed to cold, the contact of air, and a state of rest; but John Hunter and Hewson demonstrated, by experiment, that this phenomenon could not be referred to either of these causes. Hewson took fresh blood and froze it, by exposing it to a low temperature; the blood was afterward melted, and it became fluid, and shortly coagulated as usual. John Hunter obtained a similar result. Thus it was proved that coagulation of the blood is not produced by cold. It seems even that a temperature somewhat high is favourable to

its coagulation. Experiment also proves that the blood runs into a mass when deprived of the contact of air, and agitated; in general, however, repose, and the contact of air, favour its coagulation.

But so far from referring the coagulation of the blood to any physical influence, it must undoubtedly be considered as essentially vital; that is, as giving demonstrative evidence that the blood is endowed with life. We shall see, hereafter, of what importance the property of coagulating, possessed by the blood and other fluids, is in many of the phenomena of nutrition. To form a more precise idea of the coagulation of the venous blood, I placed in the focus of a microscope a drop of this fluid while it was still in a liquid state; it appeared like a red mass, but, as soon as it began to coagulate, the edges became transparent and granulated; the solid part, being almost opaque, formed an infinite number of fine meshes, or cells, which contained the fluid part, which was the most transparent. It was this disposition which gave to the edge of the drop of blood its granulated aspect. By degrees these meshes became enlarged by the retraction of the solid parts; in many places they entirely disappeared, and there only remained between the external circumference of the drop of blood and the edge of the central coagulum an arborescent appearance, very analogous to what we have described in speaking of the lymph; their divisions communicating with each other like the vessels and nerves of leaves. This experiment must be made by a diffused or artificial light, for the direct light of the sun produces dessication, without coagulation. Under many circumstances the blood coagulates, even when contained in the vessels; but in general this phenomenon arises from disease. Some authors thought they had remarked that the blood, in coagulating, became warmer; but John Hunter, and very recently Mr. J. Davy, have proved that there is no elevation of temperature.

At the period when galvanism attracted so much attention in France, it was supposed that if a portion of the coagulum, recently formed, was submitted to a galvanic current, it contracted itself like the muscular fibres. I have often endeavoured to produce this effect, by submitting portions of coagulum, at the moment of their formation, to the action of the pile; but I have never seen anything of the kind. I have varied these attempts in different ways, but have never been more fortunate. Very recently I have repeated this experiment, with M. Biot, but the result was the same.

The analysis of the coagulum of venous blood by M. le Canu has given the following result:

	1st Analysis.	2d Analysis.
Water	780.145	785.590
Fibrine	2.100	3.565
Albumen	65.090	69.415
Colouring matter	133.000	119.626
Fatty crystallizable matter . .	2.430	4.300
Oily matter	1.310	2.270
Extractive matter soluble in alcohol and water . .	1.790	1.920
Albumen combined with soda .	1.265	2.010
Chlorine of sodium, " of potassium, Sub-carbonate, Phosphate, Sulphate . . .	8.370	7.304
Sub-carbonate of lime, " of magnesia, Phosphate of lime, " of magnesia, " of iron, Peroxide of iron .	2.100	1.414
Loss	2.400	2.586
Total	1000.000	1000.000

The analysis of the venous blood, such as we have already pointed out, makes us acquainted with the peculiar elements of this fluid; but as all the substances absorbed in the intestinal canal, the serous membranes, and the cellular tissue, are mixed immediately with the venous blood, the result must be, that the composition of this fluid will vary in proportion to the matter absorbed. There will be found, under different circumstances, alcohol, æther, camphor, and salts, which it does not contain generally, when these substances have been submitted to absorption, in any part of the body. The greater or less degree of promptitude with which the blood runs into a mass, the solidity of the coagulum, the separation of the serum, the formation of an albuminous coat upon its surface, and the particular temperature of the fluid in or out of the vessels, are phenomena which we shall examine in the article *Arterial Blood.*

Apparatus of the Venous Blood.

This is composed, first, of the veins; second, of the right auricle and ventricle of the heart; third, of the pulmonary artery.

Of the Veins.

The arrangement of the veins in the tissue of the organs escapes our senses. When we first begin to distinguish them, they are presented under the form of an infinite number of small tubes, exceedingly delicate, communicating with each other in a sort of very fine net-work; they soon increase in volume, still preserving their reticulated arrangement. They in this manner form ves-

sels, the capacity, form, and disposition of which differ in each tissue, and even in each organ. Some organs appear almost entirely formed of venous radicles; such are the spleen, the cavernous parts of the penis, the clitoris, the iris, the nipple, and the ureter, &c. When we force an injection into one of the veins which pass out from these different tissues, they but rarely become entirely filled with the injected matter, which does not happen often, when the injection is pushed into the arteries. The incision of these parts in man, or in living animals, causes blood to be thrown out, which has all the appearance of venous blood.

The venous extremities communicate with the arteries and lymphatic vessels; anatomy leaves no doubt on this point; but it appears that those extremities, the disposition of which is unknown, are also open on the different surfaces of the membranes, the cellular tissue, and even the parenchyma of the organs. M. Ribes, having forced mercury into one of the branches of the vena portæ, saw the villosities of the intestinal mucous membrane filled with this metal, which spread itself into the cavity of the intestine. In forcing air from the venous trunks towards their origin, and overcoming the resistance of the valves, which is very easy in those bodies which are in a state of incipient putrefaction, the same anatomist has always found the air spread with great facility into the cellular membrane, although no sensible rupture of the venous walls had taken place. I have made similar remarks in forcing the air, or other fluids, into the veins of the heart. These facts, which have taken place since my experiments on venous absorption, of which I shall speak hereafter, agree perfectly with them.

The veins of the brain surround it on every side; they form a great part of the pia mater, and penetrate into the ventricles, where they contribute to form the plexus choroides. Those of the testicles represent a very fine net-work, which covers the spermatic vessels, while those of the kidneys are short and voluminous. In leaving the organs to pass towards the heart, the veins affect a very different arrangement. In the brain they are lodged between the laminæ of the dura mater, protected by them, and are known by the name of sinuses. In the spermatic cord they are flexuous, anastomosing frequently, and forming the pampini-form body: About the vagina they are reticulated, in the uterus they are very voluminous, with numerous flexuosities. In the extremities, head, and neck they are distinguished into deep-seated, which accompany the arteries, and superficial, which are placed immediately under the skin, in the midst of the lymphatic trunks, which are found there. In proportion as the veins become distant from the organs, and approach the heart, they diminish in number and increase in volume, so that all the veins of the body, which are innumerable, terminate in the right ventricle of the heart by three trunks, the vena cava, inferior and superior, and the coronary vein.

I have said that the small veins communicate with each other by frequent anastomoses; this disposition exists also in the large veins, and in the trunks of the veins. The superficial trunks in the extremities communicate with the deep-seated; the veins of the external part of the head, with those of the internal; the external, with the internal jugulars; and the vena cava superior, with the inferior, &c. These anastomoses are advantageous to the course of the blood in these vessels. Many veins exhibit in their cavities folds of a parabolic form, called valves; they have two free surfaces, and two edges, the one of which adheres to the walls of the vein, while the other is left floating in it. The first is more distant from the heart, and the other much nearer to it. The number of the valves are not always the same: in general they are the most numerous where the blood has to rise against its own gravity, and they have only a weak pressure to support them from the surrounding parts; they are wanting, on the contrary, in those parts where the veins are exposed to an habitual pressure, which favours the circulation of the blood, and in those which consist of canals not extensible. They rarely exist in those veins which are less than a line in diameter. Sometimes the size of the valves is so great as to fill completely the cavity of the vein; but at others they are evidently too small to produce this effect. All anatomists have thought that this arrangement depended on primitive organization; but Bichat thought he had discovered that it arose from the state of contraction or dilatation of the veins when death took place.

I have endeavoured to satisfy myself of the correctness of Bichat's idea; but I acknowledge I have been unable to do it. I have not perceived that the distention of the veins had any influence upon the size of the valves; it has seemed to me, on the contrary, that they remain always the same; but that their form was altered by their contraction or dilatation; and it was probably this which deceived Bichat.

The veins are formed by three membranes, placed one over the other. The external is cellular, dense, and difficult to rupture. If we can depend on the works of anatomists, that which comes next is formed of parallel fibres in the direction of the length of the vessel; and that this is easiest to be perceived when the vein is large and contracted. I have endeavoured, but without success, to distinguish the fibres of the middle membrane of the vein. I have always observed excessively numerous filaments interlaced in all directions, but which seemed to assume the appearance of longitudinal fibres when the vein is folded longitudinally, a disposition which is always observed in the large veins. The subcutaneous veins of the extremities, the walls of which are very thick, will be found to afford the greatest facility in examining the arrangement of this membrane. We are ignorant of the chemical nature of the fibrous coat of the veins; from some experiments which I have made, I suspect it is chiefly fibrine. It is extensible and firm, and does not present otherwise any peculiarity in the

living animal, in which it resembles muscular fibres. When irritated with the point of a scalpel, or submitted to a current of galvanic fluid, it does not exhibit any sensible contraction. The third membrane of the veins or internal tunic is extremely thin, and very much folded on that surface which is in contact with the blood; it is very flexible and extensible, at the same time presenting a considerable resistance; it supports, for example, without being ruptured, the pressure of a ligature drawn strongly around it. Some of the veins, for example, the sinuses of the brain, the venous canals of the mouth, and the sub-hepatic veins, have their walls alone formed by this membrane, being almost entirely destitute of the two others.

These three tunics together form a very elastic tissue. In whatever direction the veins may be enlarged, they resume immediately their primitive form; nor can I imagine on what ground Bichat has asserted that they are destitute of elasticity. Nothing can be easier than to satisfy ourselves that they possess this physical property to a very great extent. Another physical property that the walls of the veins possess in a very high degree is that of imbibition. They act in this respect, after death and during life, like sponges with very fine cells, filling themselves with any liquid brought in contact with them. A large number of arteries and veins, called the *vasa vasorum*, and filaments of the great sympathetic, are sent to the veins; they are, therefore, far from being exempted from those diseases to which the other parts of the animal body are subject. They are sometimes affected by inflammation.

Of the Right Cavities of the Heart.

The heart is so well known, that it seems hardly necessary to insist much upon its form and structure. I shall only allude to its principal characters. In man, the mammalia, and birds, it is formed into four cavities; two superior, which are called *auricles*, and two inferior, which are called *ventricles*. The left auricle and ventricle belong to the apparatus of the arterial blood; the auricle and ventricle of the right side make a part of that of the venous blood.

It is not very easy to describe the form of the right auricle; its transverse diameter is the greatest; its cavity exhibits, at its posterior part, openings from the vena cava, superior and inferior, and coronary vein; internally it presents a depression called the *foramen ovale*, which is open in the fœtus, but closed in the adult. At the bottom of the auricle is a large opening, which conducts into the right ventricle. The internal surface of the auricle presents a greater number of fleshy masses or columns, which are rounded or flattened, and which cross each other in various directions, exhibiting a sort of spongy tissue spread over the internal surface of the auricle, and forming a coat of considerable thickness. At the place where the vena cava inferior is connected with the auricle is a fold of the internal membrane, which is called the *Eustachian valve*.

The external and anterior face of the right ventricle is very near to the sternum, so that it is brought in contact with it when its cavity is distended with blood. We shall see hereafter the importance of this remark. The right ventricle is a more spacious cavity, and has thicker walls than the auricle; it is of the form of a triangular pyramid, the base of which corresponds to the auricle and pulmonary artery, and its apex to that of the heart; all its surface is covered with long and rounded projections, which are called *columnæ carneæ;* their arrangement is very irregular; like those of the auricle, they form a reticulated or cavernous tissue through the whole extent of the ventricle, particularly towards its apex. The columnæ carneæ of the ventricle, being generally larger than those of the auricle, form also a network, the meshes of which are coarser; some arising from the surface of the ventricle, terminate in forming one or more tendons, which are attached to the loose edge of the tricuspid valve, which is placed at the opening, by which the auricle and ventricle communicate with each other. At the side, and a little to the left of this, is the orifice of the pulmonary artery. The walls of the auricle and ventricle are formed of three tunics: the one exterior is of a serous nature; the internal is analogous to that of the internal membrane of the veins; and the middle is chiefly muscular and contractile; this coat is thin in the auricle, but of great thickness and strength in the ventricle. The innumerable fibres which compose it have a very intricate arrangement; many respectable authors have endeavoured with great labour to ascertain their direction; but notwithstanding their patience and address, the disposition of these fibres is still but little known. Happily, it is not necessary for us to form an exact idea on this point to enable us to comprehend the action of the auricle and ventricle. The heart has arteries, veins, lymphatic vessels, and nerves, which arise from the great sympathetic, and are distributed to its walls and arteries, and perhaps even to its muscular tissue.

Of the Pulmonary Artery.

This artery arises from the right ventricle, and passes towards the lungs. At first it forms but a single trunk; soon it becomes divided into two branches, one of which is sent to the right, and the other to the left lung; each of these branches are divided and subdivided until they form an infinite number of small vessels, the tenuity of which is so great that they are at least imperceptible by our senses. The divisions and subdivisions of each of these branches of the pulmonary artery are remarkable in this, that they do not communicate with each other before becoming extremely small; the last divisions appear to be continuous immediately with the roots of the pulmonary veins. The pulmonary artery is formed of three tunics: the external is very strong, and of a cellular texture; the internal is very smooth on its internal surface, and is always lubricated by a thin fluid; the middle tunic has circular fibres, which are very elastic, and were

long thought to be muscular, though they evidently do not possess that character; its chemical nature was ascertained with precision by M. Chevreul. It is formed by the yellow elastic tissue; an immediate principle, distinct from all others. It is to this tissue that the artery principally owes its elasticity. But this property is only preserved while the tissue is penetrated by water; when deprived of it, it becomes friable. It is, then, highly probable that the yellow membrane of the pulmonary artery imbibes continually the aqueous part of the blood, and thus preserves its great elasticity, its peculiar characteristic. The tissue of the walls of the artery, and of the pulmonary capillaries, easily imbibes all the substances with which it happens to be brought in contact. Like all the membranes, it is readily traversed by vapours and gases.

Course of the Venous Blood.

According to the most distinguished physiologists, this is still but imperfectly understood. We shall only describe at present its most apparent phenomena, reserving more doubtful questions until we speak on the relations which exist between the course of the blood in the veins and arteries. We shall then speak of the cause which determines the entrance of the blood into the venous extremities. In order to form a general, but just idea, of the course of the blood in the veins, it is necessary to recollect that the sum total of the cavities of the small veins forms a much larger cavity than those of the large, into which they pour their contents; and these, again, bear the same relation to the trunks in which they terminate. In consequence of this, the blood which goes from the extreme veins passes always from a larger to a smaller cavity. The following hydrostatic principle is, therefore, perfectly applied in this instance. When a fluid passes through a tube which is full, the quantity which traverses in a given time the different sections of the tube must be always the same; but when the tube becomes larger its velocity diminishes, and increases when the tube is smaller.

Experience confirms the exactness of this principle, and the justness of its application to the course of the venous blood. If we cut across a small vein, the blood passes out very slowly, but it escapes much more rapidly from a large vein. Many veins are destined to transport the blood contained in an organ towards the large trunks. In consequence of their frequent anastomoses, the compression, or even tying one or more of the veins, does not prevent, nor even diminish the quantity of blood which is returned towards the heart; it only acquires a greater degree of velocity in the veins which remain open. When a ligature is applied about the arm, preparatory to performing the operation of bleeding, the following phenomena take place. In the ordinary state, the blood which is carried to the forearm and hand returns towards the heart by four deep-seated, and at least as many superficial veins. When the ligature is passed around the arm, the blood no longer

passes by the sub-cutaneous veins, and traverses with difficulty those which are deep-seated. If one of the veins be then opened at the fold of the arm, a continued jet will be formed, which lasts as long as the ligature remains tight, and ceases when it is removed.

We often find the veins not much distended with blood; when, however, this fluid passes with the greatest rapidity, the reverse is the fact. In the extreme veins it is very little the case. For a reason easy to be understood, those circumstances which accelerate the motion of the blood in the veins increase also the distention of the vessels. The introduction of the blood into the veins taking place in a continuous manner, every cause which operates as an obstacle to its course produces a distention of the vein, and a greater or less degree of stagnation of the blood.

The walls of the vein appear to have a very feeble influence upon the course of the blood. They yield easily when its quantity is increased, and contract again when it is diminished. But this contraction is extremely limited; it is not sufficient to expel the blood entirely from it; this is constantly found to be the case in the recent subject. I have often seen the veins empty in the living animal, and at other times I have observed that the column of fluid was far from filling up entirely the cavity of the vessel.

A great number of the veins, such as those of the mouth, the sinuses of the dura mater, testicle, and the liver, the walls of which form inflexible canals, can have no influence upon the motion of the blood that passes through their cavities. The venous blood that is poured into many of the tissues, particularly the spongy tissue of the vertebræ, can evidently receive no impulse from the walls of the cavities through which it passes. We must attribute always the faculty which the veins have of contracting when the column of blood is diminished, to the elasticity of their walls, and not to a contraction which has any analogy to that of the muscles. This contraction is much more remarkable in those which have thick walls like the superficial veins. If the veins have of themselves but little influence upon the course of the blood, there are many auxiliary causes the action of which is very manifest. All compression, whether continued or alternate, exerted upon a vein can, when it is sufficiently strong to flatten the vein, obstruct the passage of the blood. If it be moderate, it opposes the dilatation of the vein from the pressure of the blood, and thus favours its motion.

The habitual pressure which the skin of the extremities exerts upon the veins running beneath it, is one cause which renders the course of the blood in these vessels more rapid and easy. We cannot doubt this, as those circumstances which diminish the contractility of the tissue of the skin are, sooner or later, followed by a considerable dilatation of the veins, and in some cases the production of varices. It is also known that an appropriate bandage restores the veins to their ordinary dimensions, and the course of the blood to the internal parts. In the abdomen, the veins are

submitted to the alternate pressure of the diaphragm and abdominal muscles; a cause which is favourable to the progress of the venous blood in this part. The veins of the brain support also a considerable pressure, which must produce the same result. Whenever the blood in the veins passes in the direction of its weight, its progress is much easier than when it has to mount against it. We must not neglect to notice the relations of these auxiliary causes to the arrangement of the veins; where they are the most remarkable, the veins do not possess valves, and their walls are very thin, as we notice in the abdomen, chest, cavity of the cranium, &c. But where they have less influence, the veins are furnished with valves, and the walls are thicker; lastly, where they are very weak, as in the sub-cutaneous veins, the valves are numerous, and the walls of considerable thickness.

If we wish to form a comparatively exact idea in this case, we have only to examine the internal saphæna, the crural, and the commencement of the external iliac veins, on a level with the opening of the femoral aponeurosis, destined for the passage of the saphæna vein; the contrast in the thickness of the walls will be found very striking. I have lately made this comparison in the body of a criminal who was very muscular. The walls of the saphæna were as thick as those of the carotid artery; the crural, and especially the external iliac, had walls which were much thinner.

We must take care, however, lest we confound these circumstances, favourable to the course of the blood in the veins, with causes which act in a very different manner. For example, it is generally known that the contraction of the muscles of the fore arm and hand, during bleeding, accelerates the motion of the blood which escapes through the opening of the vein. Physiologists assert that the muscles, in contracting themselves, compress the deep-seated veins, and expel the blood, which passes then into the superficial veins. If this were the case, the acceleration would be only instantaneous, or, at least, of very short duration; while it is known to continue, in general, during the contraction. We shall see hereafter how this phenomenon may be explained. When the feet are plunged for some time in warm water, the subcutaneous veins swell: this is generally attributed to the rarefaction of the blood. The true cause appears to me to be the increase in the quantity of the blood which is carried to the feet, and especially to the skin; this augmentation would naturally accelerate the motion of the blood in the veins, inasmuch as in a given time they are traversed by a larger quantity of blood.

From the preceding remarks, we may easily understand that the venous blood must be frequently stopped, or at least its course retarded, either from the too great pressure which the veins experience in the different positions that the body assumes, or by different foreign bodies which are applied to it, &c. Hence the necessity of the numerous anastomoses, which we have said exist not only between the extreme veins, but those which are larger,

and also in the large trunks. In consequence of these frequent communications, should one or more of the veins be compressed, so as not to allow the blood to pass, this fluid is turned aside, and arrives at the heart by other routes. One of the uses of the vena azygos appears to be to establish an easy communication between the vena cava superior and inferior. I believe, however, its principal use is to afford a common termination for the greater part of the intercostal veins.

There is nothing very obscure in the action of the valves of the veins; they are nothing else but true valves, which oppose the return of the blood towards the venous extremities, and which fulfil this office most perfectly when they are large; that is, when they are favourably disposed for closing the cavity of the vein entirely. The friction of the blood against the walls of the veins, its adhesion to these walls, and its imperfect fluidity, must modify the motion of the blood in the veins, and generally tend to retard it. But it is impossible, in the present state of physiology and hydrostatics, to assign, with precision, the *particular* effect of each of these causes.

What we have said of the course of the venous blood is enough to show that it is very much modified by an infinite number of circumstances. We shall have occasion to examine this more particularly hereafter, when we come to examine generally the circulation of the blood, and the difference in quality between that of the arteries and veins. The venous blood from every part of the body arrives at the right auricle of the heart by three trunks, which we have already mentioned, viz., two which are very voluminous, called the vena cava inferior and superior, and a small one called the coronary vein. It is very probable that the blood passes through each of these veins with very different degrees of rapidity. It is evident that these three columns of fluid endeavour to penetrate into the auricle at the same time, and that this effort must be considerable.

Absorption exerted by the Veins.

Not only do the venous extremities receive blood directly from the extreme arteries, but they present another remarkable phenomenon. Every kind of gas or fluid, when put in contact with the different parts of the body except the skin, passes immediately into the small veins, and arrives soon at the lungs with the venous blood. The same thing takes place with all those solid substances capable of being dissolved by the blood or secreted fluids. In a very short time they are introduced into the veins, and are transported to the heart and lungs; this introduction is called *venous absorption.*

If we wish to form a distinct idea of this property, common to all the veins, we have only to introduce an aqueous solution of camphor into one of the serous or mucous cavities of the body, or to bury in the tissue of one of the organs a morsel of solid camphor. Soon after, the air which passes from the lungs of the ani-

mal will possess, very distinctly, the odour of camphor. This experiment is easy to be made upon man, after the administration of an enema; it is seldom that, in the course of five or six minutes, the breath does not exhibit strongly the odour of this drug. Almost all the odoriferous substances which do not combine with the blood produce similar effects. In the experiments which I made upon the absorption of the veins, I have found that its rapidity varied according to the different tissues. It is, for example, much more rapid in the serous than the mucous membranes; it is much more prompt in those tissues which abound with sanguineous vessels than those which contain few, &c. The corrosive quality of the fluids or solids submitted to absorption does not prevent this being effected. It appears, on the contrary, to be much more prompt than in those substances which do not attack the tissues.*

The intestinal villosities, formed partly by the venous extremities, absorb in the small intestine all tho fluids except the chyle. It is easy to satisfy ourselves of this by introducing into the intestine those substances which are strongly odorous or sapid, and susceptible of being absorbed. As soon as the absorption begins, and as long as it continues, the properties of these substances may be recognised in the blood taken from the branches of the vena porta, though we cannot distinguish them in the lymph until a considerable time after the absorption has begun. We shall show, in the sequel, that they do not arrive at the thoracic duct through the medium of the lacteal vessels, but through the communications of the arteries with the lymphatics. It is well known that all the veins of the digestive organs unite together in a single trunk, which is divided and subdivided in the tissue of the liver. This structure deserves to be noticed. In consequence of the great extent of the mucous membrane with which the drinks and other fluids are in contact, and the rapidity of their absorption by the mesenteric veins, a considerable quantity of fluid foreign to the animal economy may traverse the venous system of the abdomen in a given time, and alter the composition of the blood. If the fluid, in this state, passed on to the lungs, and from thence to the rest of the organs, there would result the most serious consequences, as the following experiments will demonstrate.

I found that fifteen grains of bile forced suddenly into the crural vein generally killed the animal in a few minutes. If a certain quantity of atmospheric air be introduced rapidly into the same vein, the same effects will follow; but an injection made in the same way into one of the branches of the vena portæ will not be found to produce any inconvenience. From whence arises the difference in these results? Does the passage of foreign fluids into the animal economy, through the innumerable small vessels

* Much is said in modern works of physiology, of the peculiar sensibility of the mouths of the absorbent vessels; they are, say some, endowed with a delicate and sure tact, by which they discern those substances which are useful and suitable to them, and they refuse those substances which are injurious. These ingenious suppositions, which have a particular charm for minds eager after new ideas, are destroyed as soon as they are submitted to experiment.

of the liver, have the effect of mixing them more intimately with the blood, and, as it were, diluting them with a large quantity of this fluid, so that their chemical nature becomes somewhat altered? This becomes the more probable from the circumstance that, if the same quantity of bile or air be injected very slowly into the crural vein, it does not produce any sensible injury. It is, therefore, perhaps necessary that the veins arising from the digestive organs should pass through the liver, in order that they may mix more intimately with the blood the substances absorbed in the intestinal canal. Whether this effect takes place or not, it cannot be doubted that those agents which are absorbed from the stomach and intestines do pass immediately through the liver, and that they cannot but have an influence upon this organ which merits the attention of physicians.* We have said above that the skin makes an exception to the general law that the veins absorb in every part of the body. This proposition merits a particular examination.

When the skin is deprived of the epidermis, and the sanguineous vessels which cover the external surface of the chorion are exposed, absorption takes place, as it does in every other part. After having applied a blister, if we cover the surface, which has been deprived of its epidermis, with a substance the effects of which upon the animal economy we can easily observe, a few minutes are often sufficient for them to be manifested. Caustics applied to ulcerated surfaces have often produced death. In order that the inoculation of the smallpox, or the vaccine disease, may succeed, it is necessary to take care to place the substance beneath the epidermis, and, of consequence, to place it in contact with the subjacent sanguineous vessels.

But it is very different when the skin remains covered with its epidermis. Unless the substances in contact with it are of a nature to change its chemical composition, or to excite an irritation in the corresponding sanguineous vessels, there is no sensible absorption. I know that this result is contrary to the received opinion on this subject. We think, for example, that when the body is plunged in a bath, it absorbs the surrounding liquid; it is on this idea that the use of nourishing baths of milk and soup was founded. In a work recently published, M. Seguin has placed the point beyond doubt, that the skin does not absorb water when placed in it, by a series of very careful experiments. To satisfy himself if the same thing would take place with other fluids, this gentleman made the following experiments upon persons affected with syphilitic diseases. He plunged their feet and legs in baths composed of sixteen pounds of water, with one ounce of corrosive sublimate dissolved in it; each bath lasted one or two hours, and

* It would be curious to inquire why, of all the vessels of the liver, the branches of the vena portæ alone, by the disposition of their external membrane, called the *capsula glissonii*, are capable of contracting upon themselves when the quantity of blood which runs through them diminishes. Perhaps this arrangement is most favourable to the course of the venous blood, which, to this portion of the vena portæ, passes from a narrow part into one that is large, while everywhere else it passes from a part that is large into one that is narrow.

was repeated twice, daily. Thirteen patients were submitted to this treatment during twenty-eight hours, who did not present any evident marks of absorption; a fourteenth patient presented signs of this having taken place after the third bath, but he had excoriations on both his legs; two others who were in the same situation exhibited the same phenomenon. In general, absorption does not take place, excepting in those persons where some portion of the epidermis is removed; however, at a temperature of 72° Fahrenheit, the corrosive sublimate is sometimes absorbed, but the water never.

Among the experiments of M. Seguin, there is one which appears to throw great light upon the absorbing faculty of the skin. After having weighed seventy-three grains of calomel, the same quantity separately of gamboge, scammony, *salt of Alembroth*, and tartar emetic, M. Seguin caused a patient to lie down on his back; and having washed the skin of the abdomen nicely, he applied carefully upon the surface these five substances; he then covered each of the places with a watch-glass, maintaining it in its situation with a linen bandage. The heat of the chamber was kept at about 68° Fahrenheit. M. Seguin remained with the patient the whole time, in order to prevent mistakes; the experiment lasted during ten hours and a quarter. The glasses were then removed, and the substances collected with great care, and weighed. The calomel was reduced to seventy-one grains and a third; the scammony weighed seventy-two grains and three quarters; the gamboge, a little more than seventy-one grains; the salt of Alembroth was reduced to sixty-two grains, several pustules being developed on the spot where it was applied; the emetic tartar weighed sixty-seven grains. It is evident, from this experiment, that those substances which were the most disposed to irritate the skin, and combine with the epidermis, were partly absorbed, while with the others this was not the case.

But that which does not take place from a simple application may take place from frictions upon the skin with certain substances. We cannot doubt that mercury, alcohol, opium, camphor, vomits, purgatives, &c., penetrate by means of the venous system. It appears that these different agents pass through the epidermis either through the pores, or are insinuated into the openings by which the hairs or insensible transpiration pass out. Thus, in considering the absorption of the skin, we perceive that this membrane differs from the other surfaces of the body only in being covered by the epidermis. While this coat remains perfect, and is not perforated by the substances placed in contact with the skin, no absorption takes place; but whenever this is the case, this action occurs in the skin as in every other part.

I am not ignorant that many persons will be surprised at my not hesitating to attribute to the veins the faculty of absorption, while the general opinion is that all absorption is effected by the lymphatic vessels. But from the facts already related under the article *Absorption of the Lymph*, and some others which I am now

about to add, it is impossible for me at present to think otherwise. Besides, the opinion which I support is by no means new; Ruysch, Boerhaave, Meckel, and Swammerdam professed it, and Haller supported it, though he was not ignorant of the anatomical labours of John Hunter. M. Delille and myself separated the thigh of a dog from the body after having first stupified him with opium, for the purpose of avoiding the pain inseparable from a tedious experiment. We left the crural artery and vein alone untouched, preserving thus the communication between the thigh and trunk. These two vessels were dissected with very great care; that is, they were insulated to about the extent of two inches; their cellular coat was removed, lest it should conceal some lymphatic vessels. Two grains of a very subtle poison (*upas tienté*) were then introduced into the foot. The effects of the poison were as prompt and severe as if the thigh had not been separated from the body, so that the effects were manifested before the fourth minute, and the animal died before the tenth.

It may be objected, notwithstanding all the precautions which were taken, that the walls of the crural artery and vein still contained lymphatics, and that these vessels were sufficient to give passage to the poison. To do away this objection, I repeated upon another dog the preceding experiment, with this difference: I introduced into the crural artery the barrel of a small quill, upon which I fixed the vessel by two ligatures; the artery was divided in a circular direction between the two ligatures; I then did the same with the crural vein; thus all communication between the thigh and the rest of the body was interrupted, except the arterial blood, which passes to the thigh, and the venous which returned from it. The poison introduced into the foot produced its effects in the ordinary time; for example, about four minutes.

From this experiment, we cannot doubt that the poison did pass from the foot to the trunk through the crural vein. To render this phenomenon still more evident, we have only to press the vein between the fingers at the moment when the poison is beginning to develop itself; these effects cease soon, but they return as soon as the vein is left free, and cease if we compress it anew. We may thus graduate them according to our pleasure. We may add to these facts, which appear to me to be decisive, the interesting experiments made by Flandrin. In the horse, the substances contained both in the large and small intestines are generally mixed with a large quantity of liquid, which is more or less abundant as we approach towards the rectum; it is absorbed as it passes over this part of the intestinal canal. Now Flandrin ascertained that the fluid contained in the lacteal vessels did not possess any odour analogous to that of this intestinal fluid; but, on the other hand, that the venous blood of the small intestines had sensibly an herbaceous taste; that of the cœcum had a sharp and slightly urinous taste; that of the colon possessed the same character in a more remarkable degree. The blood in the other parts of the body presented nothing of the kind.

A half pound of assafœtida, dissolved in an equal quantity of honey, was given to a horse; the animal was afterward fed in the usual way, and killed in about sixteen hours. The odour of the assafœtida was very distinct in the veins of the stomach, small intestines, and cœcum; it was not remarkable in the arterial blood nor the lymph. Under the article *Lymphatic Vessels*, I have spoken of the experiments of John Hunter, to prove that these vessels are the only agents of absorption. That author endeavoured also to demonstrate that the veins do *not* absorb; but these last are not more satisfactory or correct than those which we have already mentioned. "I took," says Hunter, "a portion of the intestine of a sheep; after having divided the abdominal walls, I passed ligatures upon its two extremities, and then filled it with warm water. The blood which returned by the veins of this part did not appear more diluted or lighter than that of the other veins. I then tied the artery and all its communications, and examined the state of the vein. It was not swelled, the blood was not more diluted, and it did not give any indication of the presence of the water in its cavity. The veins, therefore, do not absorb."*

How many objections present themselves to this experiment in the minds of those who think precision desirable in physiological inquiries! How could John Hunter know, from the simple appearance immediately after the experiment was performed, that the water was not absorbed, and not mixed with the blood of the vein? Again, how could this author, otherwise so eminent, have supposed that the action of the vein would continue when a ligature was passed around the artery? It would have been first necessary to determine the effect of tying an artery upon the motion of the blood in the corresponding vein; a thing which had never been done. In another experiment, the same physiologist injected warm milk into a portion of the intestine; shortly afterward he opened the mesenteric vein, and collected the blood as it passed out, and because he could not distinguish any trace of the milk, he concluded that no absorption of this fluid had taken place by the vein. But at the time of Hunter, they were far from possessing any means of detecting a small quantity of milk in a certain quantity of blood. At the present period, when animal chemistry is far more advanced, it is a difficulty not easily overcome.

These two experiments, when fairly considered, ought not to have any influence in deciding the doctrine of venous absorption. The other experiments, the number of which is six, are far from being conclusive, but, on the contrary, are still more defective. In a word, if it were necessary to adduce stronger evidence in favour of venous absorption, I would refer the reader to many parts of the body in which the most expert anatomists have never been able to detect lymphatic vessels, or any other but blood-vessels, such as the eye, the brain, the placenta, &c., though absorption

* Medical Commentaries, chap. v.

takes place with the same promptitude as in every other part of the body. I will add, that all those animals which do not possess vertebræ have blood-vessels, but not lymphatics, while absorption still manifestly takes place. Finally, the thoracic duct is much too small to afford a passage to all the substances absorbed in the various parts of the body, and particularly the drinks.* All these phenomena are at once satisfactorily explained when the absorption of the veins is admitted. Facts, experiments, and reason, then, concur in favour of the doctrine of venous absorption.†

Such was the state of this question when the first edition of this work was published. But since that time science has taken an important step; it has lost a prejudice, and acquired a fact of extreme interest.

It was believed, for at that time physiology consisted of creeds, that the living tissues, particularly the membranes, the walls of the vessels, &c., in consequence of their vitality, were incapable of imbibing various substances which they readily imbibed after death. With this idea, it was attempted to explain absorption as a vital phenomenon. No one thought of regarding it as a physical phenomenon. Even to me, who had laboured twenty years on this subject, the idea never occurred. Extreme repugnance to acknowledge our ignorance, and a disposition to fill with fiction the voids left in science, are intellectual phenomena as remarkable as they are injurious to the progress of knowledge. The mode by which absorption takes place was unknown. Instead of directly confessing this, and entering upon proper researches to discover it, it was said "that the *living* tissues do not allow of imbibition, as takes place after death; that there were absorbent mouths which distinguished between the substances presented, receiving some and rejecting others." This was asserted and firmly believed, and the mechanism of absorption remained uninvestigated and unknown. Such must always be the consequences when the sciences are left to the dominion of the imagination instead of being guided by observation and experiment.

But I have demonstrated, by a series of experiments since that time, that the living tissues imbibe all the liquid substances which are in contact with them. The same thing also occurs with solid substances, provided they are soluble in the humours, particularly the serum of the blood. This general fact being established, absorption, which has so much occupied physiologists, exercised their imaginations, and caused so many controversies, becomes a sensible and almost purely physical phenomenon. It is no longer necessary to inquire whether the veins or lymphatics absorb, inasmuch as all the tissues are endued with this property.

The following experiments, I conceive, place this beyond doubt.

* Some persons drink as much as twelve pounds of mineral water in the course of a few hours, and reject it through the kidneys in the same time.

† To recapitulate what we have said of the organs of absorption, in a general point of view, we may remark, first, that it is certain that the lacteal vessels absorb the chyle; second, that it is doubtful whether they absorb anything else; third, that it has not been demonstrated that the lymphatic vessels possess the property of absorption, but it is proved that the veins are endowed with this power.

They are extracted from my memoir on the mechanism of absorption.*

In a public lecture on the *modus operandi* of medicines, I showed on a living animal what are the effects of the introduction of a certain quantity of warm water at 30° of the centigrade thermometer in the veins. In making that experiment, it occurred to me to see what would be the effect of artificial plethora on the phenomena of absorption. With this purpose, after having injected about a pint of water into the veins of a dog of medium size, I introduced into its pleura a moderate dose of a substance the effects of which were well known to me. I was struck at observing that its effects were not perceptible until many minutes after the ordinary time. I immediately repeated this experiment on another animal, and obtained a similar result. In many other experiments the effects were developed at the proper time, but were sensibly weaker than might have been expected from the dose submitted to absorption, and were continued much beyond their ordinary term.

In another experiment where I had introduced about two pints of water, as much as the animal could endure, the ordinary effects no longer took place ; absorption appeared to be prevented. After having waited nearly half an hour for effects which generally required but two minutes to develop themselves, I came to the following conclusion: if the distention of the sanguineous vessels is the cause of the defective absorption, if the distention ceases, the absorption ought to take place. I immediately made a large bleeding from the jugular vein, and I saw the effects manifest themselves in proportion as the blood flowed.

I might also make the opposite experiment, *i. e.*, diminish the quantity of blood, and see if the absorption would be more prompt. This happened precisely as I had anticipated. An animal was bled to half a pound; effects which ordinarily did not occur until the end of two minutes, were exhibited in the course of thirty seconds. But it might be said that these effects were less attributable to the distention of the sanguineous vessels than the change in the nature of the blood, which was opposed to absorption. To remove this objection, I made the following experiment: a free bleeding was practised in a dog, and the blood lost was replaced by an equal quantity of water, after which there was injected into the pleura a certain quantity of a solution of the nux vomica. The effects were as prompt and intense as if the nature of the blood had not been changed. Thus it is to the distention of the vessels that we must attribute the defective absorption, and not to the altered quality of the blood.

Thus I became, as it were, master of a phenomenon that had been heretofore an impenetrable mystery to me. Having it in my power to prevent it, produce it, render it rapid or slow, strong or weak, its nature could not readily escape my investigation.

* See my Journal de Physiologie, t. i.

In reflecting on the constancy and regularity of this phenomenon, it was no longer possible to refer it to what is called *vital action*, like the action of the nerves, the secretion of the glands, &c. It was much more reasonable to consider it as approaching a physical phenomenon. Among the most probable conjectures that presented themselves, was the supposition that absorption depended upon the capillary attraction of the vascular parietes for the absorbed substances; this united, indeed, all the facts that had been observed on this subject. On this supposition, solid substances insoluble in the humours would resist absorption; while those, on the contrary, which are capable of combining with the tissues, or being dissolved in the fluids of the body, would become absorbed, which is conformable to the facts. Almost all liquids which are capable of moistening the vascular walls, whatever might be their chemical nature, ought, according to this view, to be absorbed, which is actually the case, as is shown by experiment, even with caustic liquids. According to the same hypothesis, the more the vessels were distended, the less marked would be their absorbing power, and there would be a point at which the process would cease. The smaller and more numerous the vessels, the more rapid would be their absorption, inasmuch as the absorbing surfaces would be more extensive.

This action of the walls once recognised, nothing would be easier than to comprehend how the absorbing substances are transported towards the heart, inasmuch that, as soon as they arrived at the inner surface of the walls, they must be immediately swept into the current of the sanguineous circulation.

I the more readily adopted this supposition as I recollected distinctly that, in poisoning an animal by wounding it with a Java arrow in the thick part of the thigh, all the soft parts which surrounded the wound became of a brownish-yellow colour for several lines in thickness, having the bitter taste of the poison.

But a supposition that connects together a certain number of known phenomena is, after all, but a more convenient manner of expressing them. It does not assume the character of a theory until it is confirmed by numerous and sufficiently varied experiments. It was therefore necessary to make new researches to ascertain how far this supposition was admissible.

The affinity of the vascular walls for the absorbed matters being assumed as the cause, or, perhaps, more properly, one of the causes of absorption, this effect ought to take place after death as well as during life. This fact might easily be determined in vessels of a certain calibre; but keeping in mind the diameter, thickness, and extent of their walls relative to the capacity of the canal, experiment ought to show, though it might be slight, yet appreciable absorption.

I took a portion of the external jugular vein of a dog, this portion of the vessel, for an extent of about an inch and a half, not receiving any branch. I removed from it the surrounding cellular tissue, and attached to each of its extremities a tube of glass, and

thus passed a current of warm water through its interior. I then plunged the vein in a liquor slightly acid, and carefully collected the warm water that passed through the interior. From the arrangement of the apparatus, there could not be any communication between the interior current of warm water and the exterior acid liquid. At first the liquor thus collected did not become changed, but after five or six minutes it was sensibly acid; absorption had taken place. I repeated this experiment with veins taken from the human subject, with the same result.

There was no obvious reason why this phenomenon should not occur in the arteries as well as the veins. I made the experiment with a portion of the carotid artery of a small dog that had died the previous evening, and with precisely the same result. I farther remarked, that the more acid and higher the temperature of the exterior liquor, the more promptly the phenomenon was observed. But this remark holds good only to a certain extent; if the temperature approach the boiling point, or if the acidity be too great, the vessel becomes horny, and the absorption very slow.

If capillary absorption takes place in large vessels after death, why should it not occur during life?

If experiment did not furnish this result, all my reasonings would be confounded, and my supposition fall to the ground. I was the less assured of the success of the experiment, as I was still under the impression, of which we hear so much, of the great difference which life causes in the physical properties of the organs. But as I had frequently found occasion in my researches to doubt generally-received ideas, I was not discouraged, but made the following experiment:

I took a young dog about six weeks old; at this age the walls of the blood-vessels are thin, and, consequently, favourable to the success of the experiment. I laid bear one of the jugular veins; I isolated it perfectly through its whole length; I carefully dissected away the cellular tissues, and other structures by which it was surrounded, including some small vessels that ramified upon it; I placed it upon a cord, so that it should not be in contact with the surrounding parts; I then dropped upon its surface, opposite to the middle part of the cord, a thick aqueous solution of the alcoholic extract of the nux vomica. This substance acts with great energy upon dogs. I took care that no part of the poison should touch any other part than the vein and the cord, and that the course of the blood was free through the vein. Before the end of the fourth minute the effects of the poison began to be developed, at first weak, but soon they were so violent that it was necessary to have recourse to inflation of the lungs to prevent immediate death.

I repeated this experiment on a full-grown and much larger dog than the preceding, in which, of course, the walls of the veins were much thicker. The same effects ensued, but, as might have been anticipated, they were less prompt; the full effects were not developed until the end of ten minutes.

Satisfied with these results as regards the veins, I was desirous of ascertaining whether the arteries possessed analogous properties. But the arteries in the living animal are not in the same physical condition as the veins. Their structure is less spongy, and more dense; the walls are much thicker, and more constantly distended by the blood forced from the heart. It was therefore easy to foresee that if the phenomenon of absorption should take place, that it would be much more slowly developed than in the lungs. This was confirmed by experiments upon two large rabbits, from which I dissected with great care one of the carotid arteries. It required more than a quarter of an hour before the solution of nux vomica could penetrate the walls of the artery.

I ceased to moisten the vessel as soon the effects were manifest; one of the rabbits immediately died. To satisfy myself that the poison had really traversed the walls of the artery, and that it had not been absorbed by the small veins that might have been overlooked in my dissection, I carefully detached the vessel that had served for the experiment. I then divided it along its whole length, and requested my assistants to taste the little blood that adhered to the inner surface of the walls. They all recognised, as well as myself, the extreme bitterness of the extract of the nux vomica.

It was thus positively established that the large vessels absorb both during life and after death. It only remained to adduce direct proofs that the small vessels possess the same property. Their extreme tenuity, multiplicity, and thinness of the walls appeared to be all favourable to the production of this phenomenon.

To develop it after death, it was necessary to find a membrane in the vessels of which there could be established an interior current similar to the course of the blood. I first selected a portion of the intestine, but was obliged to renounce it in consequence of considerable extravasation into the cellular tissue, and the liquid passed with great difficulty from the artery into the vein. I took the heart of a dog that died the evening before, and forced into one of the coronary arteries warm water (30° centigrade). This water returned freely through the coronary vein into the right auricle, from which it ran into a vessel. I then poured into the pericardium a half ounce of slightly acid water. At first, the injected water exhibited no sign of acidity; but in the course of four or five minutes, it presented unequivocal traces of it. It was thus evident as respects the small vessels in the dead body. With respect to small vessels in the living body, it was not necessary for me to recur to new experiments, nor to sacrifice new animals. The experiments in my memoir "On the Organs of Absorption in the Mammiferi" left no doubt in this respect, according to the judgment of the Academy of Sciences.

A single objection might still be offered, viz., that the membranes which are permeable after death do not appear to be so during life. In the dead body, the bile transudes through the peritoneum, imparting a yellow colour to the parts which surround

the gall bladder, which does not take place during life. The permeability of the membranes in the dead body is too notorious to be denied, but it did not appear to me a necessary consequence that the membranes are impermeable during life. Supposing that the walls of the gall bladder during life permit the transudation of the bile, the current of blood in the small vessels, which chiefly constitute these walls, would carry off the bile as it becomes impregnated with it. But this cannot take place after death, as the circulation having ceased, there is nothing to carry off the infiltrated portion of bile. I have also frequently witnessed in living animals the imbibition and dislocation of the membranes from contact with colouring substances. If, for example, we inject into the pleura of a young dog a quantity of ink, in the course of an hour the pleura, pericardium, intercostal muscles, and even the surface of the heart itself, will become sensibly discoloured. This experiment is most striking in small animals, as rabbits, Guinea-pigs, mice, &c.

It appears, then, placed beyond reasonable doubt that the walls of all the sanguineous vessels, arterial and venous, living and dead, large and small, possess a physical property quite adequate to explain the principal phenomena of absorption. To affirm that this is the only property by which this process is effected, would be to transcend the limits of sound logic. In the present state of knowledge, I know of no fact which weakens this explanation, but, on the contrary, they all concur in sustaining it.

Thus, Messrs. Lavoisier and Séguin have proved, by a series of interesting experiments, that the skin does not absorb water or other substance, so long as it remains clothed with the epidermis. But the epidermis is not of the same nature as the vascular walls; it is a sort of varnish which does not imbibe, as any one may observe in his own person when in a bath. But as soon as the epidermis is removed, the skin absorbs precisely like the other structures, because the walls of its vessels are in immediate contact with the substances destined to be absorbed. Hence the necessity of placing under the epidermis the substances intended to be absorbed, as in vaccine inoculation; hence the necessity of prolonged frictions, and sometimes the use of unctuous substances, to promote the absorption of certain medicaments; hence our selection of that portion of integument where the epidermis is thinnest for making these frictions.

But under certain circumstances, the epidermis is capable of imbibition; this is daily witnessed from the application of cataplasms, from which the cuticle becomes white, opaque, and thick. The imbibition most readily takes place from the external to the internal surface, as may be readily shown in the following manner. If we carefully remove the epidermis from one of the fingers and turn it inside out, and fill the cavity with water, and then close the opening by tying around it a piece of thread, the water will transude freely to the surface, and evaporate in a few hours. If, on the contrary, you leave the external surface on the outside, the

water will evaporate very slowly, losing only a few grains of the water in twenty-four hours.

It is upon this physiological fact, very simple in the present state of our knowledge, but which I have the satisfaction of having demonstrated by the most unquestionable proofs, that the endermic method of using medicine is founded. It consists in removing the epidermis by a blister, and powdering the denuded surface with the substance that it is proposed should be absorbed. This process is often found very useful in modern therapeutics.

I shall also cite the absorption of the most irritating substances, even those which are capable of acting chemically upon the tissues. This fact is entirely opposed to the idea that absorption is a purely vital action, and that there is a sort of election or choice exercised by the orifices of the absorbents. But it is no longer surprising, if we regard absorption as a physical property.

It would be desirable to study this subject specially; to follow it in all the tissues, both during life and after death, as respects the different substances absorbed. Thus far, it has appeared to me that the serous membranes and cellular tissue, especially during life, probably in consequence of their high temperature, are the best agents of absorption. A drop of ink, for example, placed upon the peritoneum is immediately imbibed, spreading itself into a large round patch, which extends no deeper than the serous membrane. It requires some time to penetrate the subjacent tissues.

A very important fact observed by my fellow-labourer, M. Fodére, is, that galvanism has a remarkable influence in accelerating the absorption, or, rather, imbibition. If prussiate of potash be injected into the pleura, and sulphate of iron into the abdomen of a living animal, under common circumstances it requires five or six minutes for these two substances to be brought in contact by imbibition through the diaphragm. But the combination is almost instantaneous if the diaphragm be subjected to a slight galvanic current. The same phenomenon is observed if one of the liquids be placed in the urinary bladder, and the other in the abdomen, or in the lung and cavity of the pleura.

The theory of absorption by the veins proposed by me has been confirmed in a remarkable manner by Doctor Bouillaud. In studying with attention partial œdema of the limbs, he found that there was more or less obliteration of the veins in the infiltrated part. Generally fibrinous coagula obstruct the vessels; sometimes the veins are compressed by surrounding tumours. From some analogous cases, M. Bouillaud was led to suppose that dropsies of the peritoneum arise from the difficulty of the passage of the blood through the liver. Indeed, it is very rare that ascites of any considerable duration is not complicated with evident lesion of that organ. I opened the body of a man at the Hôpital la Pitié who had died of a cancer of the liver. There was considerable ascites, according to the views of M. Bouillaud; there was also a large quantity of liquid in the small intestines. It might have been said

that there was dropsy inside and out of that portion of the alimentary canal. I introduced a tube into the vena portæ, and by this tube I forced an injection of water through the liver, the liquid passing without much difficulty into the right auricle. The liver, therefore, was not completely obstructed; but the disorganization was not very profound; the tissue of the organ was easily recognised; here and there only there were some traces of lardaceous degeneration; the remainder of the parenchyma was granulated, and yellow; the liver was turned upon itself, and of a bony consistence. I do not regard this fact as opposed to the explanation of M. Bouillaud, for the liver, though permeable to an injection of warm water, may have ceased to be so, wholly or partially, to the blood. Now, from experiments on absorption, it appears that a simple distention of the sanguineous vessels is sufficient to retard, or even prevent the absorption, or, in other words, the imbibition of their walls. It may have been that the force with which the water was pushed through the liver in this case was much greater than that by which the blood was propelled through the vena portæ. It must be admitted, that in every case a general lesion of the liver, in which its structure is sensibly changed, cannot fail to act as an obstacle to the free circulation of the blood through that viscus.

Passage of the Venous Blood through the Cavities of the Right Side of the Heart.

If the heart of a living animal be exposed, we can readily perceive that the right auricle and ventricle contract and dilate alternately. These motions are so combined that the contraction of the auricle takes place at the moment when the ventricle is dilated, and *vice versa;* the contraction of the ventricle occurs at the moment of the dilatation of the auricle. Neither of these cavities is capable of being dilated without being at the same moment filled with blood, and when they contract a part of it is necessarily expelled. But such is the structure of the tricuspid and sigmoid valves, that the blood is compelled to pass successively from the auricle to the ventricle, and from this last to the pulmonary artery. We will now enter into a detail of this curious mechanism.

I have already observed that the blood contained in the three veins which terminate in the right auricle make a strong effort to penetrate into this cavity. If it be contracted, this effort is unavailing; but when a dilatation takes place the blood is precipitated into this cavity, fills it completely, and distends its walls slightly; it would penetrate into the ventricle if this cavity were not at the same moment in a state of contraction. The blood, then, is limited precisely to filling at this moment the cavity of the auricle; but this soon contracts itself, and the blood, being compressed, must escape in that direction where the resistance is least. Now there are but two openings, the one towards the *venæ cavæ*, and the other in the direction of the ventricle. The sanguineous columns which arrive at the auricle oppose a certain resistance to its pas-

sage in the first direction ; on the contrary, no obstacle exists to prevent its entrance into the ventricle, as, from its being dilated with force, it has a tendency to produce a vacuum, and thus to draw the blood from the auricle, instead of forcing it back. But in consequence of the thinness of the walls of the auricle it is incapable of a sucking dilatation, as has been asserted by many physiologists. When observed in a living but empty heart, it contracts, and afterward becomes relaxed, but the latter is rather a passive than an active dilatation. In every instance this movement is too weak to draw the blood of the venæ cavæ by a process of sucking. On the contrary, the blood, by its impulsion, penetrates into the cavity of the auricle, and distends its walls. The action of the auricle, as I have observed, is sometimes entirely different. The contraction does not take place, its cavity remaining distended with blood; at the moment that the right ventricle dilates to receive the blood, there is only a slight contraction of the auricle, chiefly dependant upon the elasticity of its walls. All the blood which passes from the auricle does not, however, enter the ventricle ; experiment has shown long since that, at each contraction of the auricle, a certain quantity of this fluid flows back into the venæ cavæ. The undulation produced by this cause may be perceived as far as the external iliac and jugular veins ; its influence also upon the course of the blood is very sensible in several of the organs, especially the brain.

The quantity of blood which flows back in this manner varies according to the facility with which this fluid is allowed to penetrate into the ventricle. If, at the moment of its dilatation, the ventricle contain still much blood which has not passed into the pulmonary artery, it can, of course, receive but a small portion from the auricle, and its reflux will, therefore, be much more considerable and extensive. This occurs when the blood in the pulmonary artery is retarded by obstacles placed in the substance of the lungs, or from the ventricle having lost its contractile power. The reflux of which we are speaking is the cause of the pulsation felt in the veins in certain diseases, and which has received the name of *venous pulsation.* Nothing of the kind occurs in the coronary vein, as its mouth is supplied with a valve which closes at the moment the auricle contracts.

The instant the contraction of the auricle ceases, the ventricle contracts, by which the blood contained in it, being pressed on every side, endeavours to escape ; it would repass very easily into the auricle did no obstacle exist, as may be inferred from what we have already said, this cavity being then in a state of dilatation. But this is prevented by the action of the tricuspid valve, which is placed at the opening between the auricle and ventricle, and will not allow the reflux of the blood from the ventricle to the auricle. Pressed by the fluid with which the ventricle is distended, and which tends to pass into the auricle, this valve yields until it gets into a line perpendicular to the axis of the ventricle ; then its three divisions perfectly close the opening, and its fleshy and ten-

dinous columns will not allow it to go any farther; this valve resists the effort of the blood, and prevents its passage into the auricle. But this is not the case with that portion of the blood which, during the dilatation of the ventricle, is placed on that side of the valve which corresponds to the auricle; it is evident that, when the valve is raised, this portion of the blood will be thrown back into the auricle, and mixed with that received from the venæ cavæ and coronary vein. Not being able to overcome the resistance of the tricuspid valve, the blood of the ventricle is compelled to enter into the pulmonary artery, into which it passes after having pushed aside the sigmoid valves, which support the column of blood contained in this artery, at the moment when the ventricle is dilated.

The dilatation of the ventricle which succeeds its contraction is so energetic that it has been considered by many persons as active, and that it results from a particular vital property of the ventricular walls. I do not know of any plausible reason for admitting this supposition, and cannot perceive why the dilatation of the ventricle should not be regarded as a simple return or relaxation of the contracted fibres, arising from their elasticity. But whatever may be the cause of the dilatation of the ventricles, it is very intense; if you grasp the heart of a living animal, you will be surprised at the extent of its dilatation. The ventricle then exerts a powerful absorbent or sucking action upon the blood contained in the auricle, which also, pressed by the force of its own impulsion, and the contraction of the auricle, penetrates suddenly into the cavity of the ventricle, and causes its rapid distention. The promptitude of the distention is such that it determines the shock of the anterior part of the ventricle against the sternum, and occasions a particular sound, easily distinguished by the ear, and which merits the attention of the physician. This sound has been attributed, but without reason, sometimes to the contraction of the auricle, sometimes to the shock of the blood upon the walls of the ventricle at the moment of its entrance into this cavity. But these explanations of the sound of which we are speaking are erroneous; for if the heart be laid bare while in action, it does not produce any sound if the sternum be taken away or even raised. The sound will again return if the sternum be replaced. We shall return to the consideration of this question when we speak of the contraction of the left ventricle.

We will now proceed to explain the phenomena most apparent and best understood exhibited by the venous blood in passing through the right cavities of the heart; there are also other circumstances which I conceive to be worthy of particular attention. We should have but a very imperfect idea of this subject if we supposed that, in each contraction of the ventricle and auricle of the heart, these cavities emptied themselves completely of the blood which they contained. In observing the heart of a living animal, we distinctly see, at the moment of contraction, the auricle or ventricle become sensibly diminished in volume; but it

is evident that, at the instant the contraction ceases, much blood still remains in the auricle or ventricle. There is only a part of the blood of the auricle which passes into the ventricle when it contracts. The same is true of the blood of the ventricle, a portion only of which passes into the pulmonary artery when the ventricle contracts; these two cavities, therefore, are always filled with blood. What is the precise portion of blood displaced, it may be inquired, and how much remains? They will vary, probably, according to the force with which the ventricle and auricle contract, the facility with which the blood traverses the pulmonary artery, the quantity of blood contained in the auricle or ventricle, and the efforts made by the three sanguineous columns which empty into the auricle.

The force of the blood when it reaches the auricle is sometimes so considerable, that the latter cannot contract; it may remain strongly distended for hours. It is only at the instant when the ventricle is relaxed that, in consequence of its elasticity, it reacts a little upon itself. This phenomenon occurs particularly at periods of great distention of the venous system. It affords a new proof that elasticity may replace contractility, and *vice versa.* In many diseases of the auricle the circulation must take place in this way.

When the blood has arrived at the heart, it is continually agitated, pressed and beaten by the motions of this organ; sometimes it flows back into the venæ cavæ, or precipitates itself into the auricle; again it passes with rapidity into the ventricle, is forced back suddenly into the auricle, and returns immediately afterward into the ventricle; and again it penetrates into the pulmonary artery, and returns afterward into the ventricle, undergoing at each displacement a violent agitation.* Agitated and pressed in this manner with such prodigious force, the blood must undergo an intimate admixture of its constituent parts during the time it remains in the cavities of the heart and pulmonary artery. The chyle and lymph which the subclavian vein receives must be distributed equally in the blood of the two venæ cavæ. These two kinds of blood must also be compounded and completely united.

I am almost tempted to believe, with Boerhaave, that the fleshy columns of the right cavities, independently of their uses in the contraction of these cavities, must have a considerable share in this agitation and admixture of the different elements of the blood. Indeed, the blood which is found in the auricle and ventricle not only occupies these large central cavities, but also the small cells formed by these columns; of consequence, at each contraction it is forced partly into these cells, and is replaced at each dilatation by a new portion of blood. Being divided thus into a great number of small masses, so as to occupy the cells when it is again united and expelled, it cannot fail, from the excessive agitation it

* It is sufficient to touch but once the heart of a living animal to form an idea of the energy of its contraction.

suffers, that the different elements of which it is composed, which have a great tendency to separate, should become thus intimately blended and combined. For the same reason, the chyle, lymph, and drinks, which are carried by the veins to the heart, and that have not become intimately mixed with the blood, must undergo this change in traversing the right cavities of the heart.

If we wish to form an idea of the influence of the right side of the heart, in this respect, we have only to force suddenly a quantity of air into the jugular vein of a dog, and examine the heart a few minutes afterward ; we shall see the air agitated and beaten about in the auricle and ventricle, forming a large mass of very fine froth. I have often observed these phenomena in living animals; and I have lately had an opportunity of confirming them upon a horse, the heart of the animal having been exposed by an incision on the lateral part of the thorax, and a section of one of the ribs.

Passage of the Venous Blood through the Pulmonary Artery.

Notwithstanding the numerous efforts of physiologists in investigating the motion of the blood in the arteries, much still remains to be done on this subject. Experience and observation are here our only faithful guides ; our explanations must necessarily be imperfect, as hydrostatics, the only science which can furnish them, has scarcely been extended to the motions of fluids in flexible tubes.* I shall not adopt the descriptions of other authors in giving an account of the motion and progress of the blood in the pulmonary artery. I prefer speaking of it at the moment when the relaxation of the right ventricle takes place, and to see afterward what happens when the ventricle contracts, and forces the blood into the artery. This method appears to me to possess the advantage of placing this phenomenon in the most striking point of view ; its importance does not seem to me to be sufficiently appreciated.

Let us suppose the artery full of blood, and left to itself; the fluid will be pressed by the walls of the vessel through its whole extent, which will have a tendency to approach each other, and efface completely its cavity; the blood, being thus compressed, will endeavour to escape on every side. Now there are but two directions in which this can take place: the one is the orifice next to the heart; the other, the infinite number of delicate vessels in which the artery terminates in the tissue of the lung. The orifice of the pulmonary artery towards the heart being very large, the blood would be easily precipitated into the ventricle, if there did

* I cannot resist quoting here the appropriate remarks of D'Alembert on this subject. "The mechanism of the human body, the velocity of the blood, and its action upon the vessels, cannot be reduced to a theory. We are ignorant of the precise action of the nerves, the elasticity of the vessels, their capacity, of the tenacity of the blood, and its different degrees of heat. Were even these things known, the great multitude of other circumstances which would necessarily enter into such a theory would probably conduct us to calculations altogether impracticable. It is one of those cases of a compound problem, one of the most simple parts of which it would be extremely difficult to resolve. When the operations of nature are too complicated," adds this illustrious philosopher, "to enable us to submit them to our calculations, experiment is the only method that remains for us."

not exist at this orifice a particular apparatus destined to prevent it. I allude to the three sigmoid valves. At the instant when the contraction of the ventricle forces the current of blood into the artery, these valves are brought in contact with the walls of the artery, and perpendicular to its axis; but the moment that the blood has a tendency to flow back in the ventricle, it places them in such a situation that they completely close up the cavity of this vessel. From the peculiar form of these valves, being that of a *cul-de-sac*, the. blood that enters into their cavity has a tendency to swell them out, and give a circular form to their fibres. This valve is divided into three portions, each of which is semicircular; now, if three semicircular bodies be brought together, there would necessarily exist a space between them. We might therefore suppose that the valves of the pulmonary artery, when they are pressed back by the blood, would leave a space by which the blood would flow back into the ventricle. It is undoubtedly true, that if each valve was single, it would assume a semicircular form; but as there are three, each acted upon by the blood at the same time, their sides are brought in contact with each other, and as they can each only be extended to a certain point, in consequence of the smallness of the space in which they are contained, they are therefore made to press each upon the other. The valves are therefore made to assume the form of a triangle, the apex of which is at the centre of the artery, and the sides in contact with each other, so as completely to intercept the cavity of the artery. Perhaps the small cartilaginous masses which exist at the apex of these triangles may be intended to close more accurately the artery at its centre.*

If we wish to see the manner in which these three valves are brought in contact with each other, it may be done in the following manner: if we inject gently wax, or prepared tallow, into the pulmonary artery, allowing it to pass from the ventricle, when the artery becomes filled the valves will be forced into, and brought in contact with each other; so that the orifice of the vessel will be closed with sufficient exactness to prevent a single drop of the injection from returning back into the ventricle. When the wax or tallow has become solid by cooling, we may examine, at our leisure, the manner in which the opening of the artery is closed up by the valves. The blood not being able, therefore, to flow back into the ventricle, will pass into the ramifications of the pulmonary veins, into which the small branches of the pulmonary artery are continued; and this will continue to be the case so long as the walls of the artery press with sufficient force upon the blood which they contain; an effect which, with the exception of the trunk and principal branches, continues until the whole of the blood is expelled. It may be supposed that the fineness of the small vessels in which the pulmonary artery terminates acts as an obstacle to the blood. This would be the case if their number

* See Sennac's Treatise on the Structure of the Heart.

were small, or if the sum of their diameters were less, or even equal to that of the trunk; but as they are innumerable, and as their aggregate capacity is much greater than that of the trunk, the current passes on with ease. It is, nevertheless, true that a state of distention or weakness of the lung renders this passage more or less easy, as will be more particularly shown hereafter.

In order that the current of blood may pass with more facility, it is necessary that the power of contraction in the different divisions of the artery should be in proportion to their size. If, for example, the action of the small vessels were superior to that of the large, while the first would expel the blood which they contained, they would not be distended by the blood coming from the second, and the fluid would therefore flow but very slowly. Now experiment shows that the contrary of this supposition is true. If the pulmonary artery of a living animal be tied immediately beyond the heart, nearly all the blood contained in the artery when the ligature was made will pass promptly into the pulmonary veins, and arrive at the other side of the heart.

We have now observed what happens when the blood contained in the pulmonary artery is exposed to the action of this vessel alone; but, in the ordinary state, at each contraction of the right ventricle, a certain portion of the blood is propelled with force into the artery; the valves are instantly raised; the artery, through the whole extent of its divisions, is distended in proportion to the force with which the heart contracts, and the quantity of blood which is thrown into it. Immediately after its contraction the ventricle becomes dilated, and at this instant the walls of the artery react upon themselves; the sigmoid valves become depressed, and close the artery until a new contraction of the ventricle raises them. Such is the second cause of the motion of the blood in the artery which goes to the lungs; they are, as we have seen, alternate; let us endeavour to appreciate their effects. For this purpose, we will examine those phenomena which are most apparent in the course of the blood through the pulmonary artery.

I have remarked, that at the moment when the ventricle forces the blood into the artery, its trunk and ramifications of a certain calibre undergo an evident dilatation. This phenomenon is called the *pulsation* of the artery. This pulsation is very strong near the heart, but grows weaker as you pass from it, and seems to cease altogether when the artery becomes very minutely subdivided. There is another phenomenon observed when we open the artery, which is a consequence of the preceding. If the opening be near the heart, and in a place where the pulsations are very distinct, the blood passes out in a jet, with a jerk; if the opening is made at a distance from the heart, and in a small branch of the artery, the jet is continuous and uniform; lastly, if we open one of the very small vessels in which the artery terminates, the blood no longer passes out in a jet, but spreads itself in a uniform sheet. We see, in the first place, in these phenomena, a new application

of the principle of hydrostatics quoted above, relative to the influence which the size of the tube has upon the fluid which runs through it; the larger the tube, the less the velocity of the fluid passing through it. As the aggregate capacity of the ramifications of the artery increases as they approach towards the lungs, the velocity of the blood is necessarily diminished.

With respect to the pulsation of the artery, and the jerk of the blood as it escapes from an opening in it, we see, evidently, that these two effects are the results of the contraction of the right ventricle, and the introduction of a certain quantity of blood into the artery, which is thus effected. Why are these two effects weakened at a distance from the heart, and why do they cease altogether in the last divisions of the artery? It is not impossible, I think, to give a satisfactory mechanical reason for this. Suppose a cylindrical canal, of a given length, with elastic walls, and filled with a fluid; if a new quantity of fluid be suddenly introduced into it, the pressure will be felt equally upon every point of the walls, which will be equally distended. Suppose, now, that this canal is divided into two parts, the sections of which, together, form a surface equal to that of a section of the main trunk of the canal; the distention produced by the sudden introduction of a certain quantity of fluid will be less perceptible in the two divisions than in the trunk; because the total circumference of the two canals, being greater than that of the one canal alone, its resistance will be greater. If we suppose that these last two are divided and subdivided indefinitely, the sum of the circumferences of the small tubes will be greatly superior to that of the great trunk; the same cause which will produce a sensible distention in the canal and its principal divisions will not be appreciable in the smallest subdivisions, in consequence of the greater resistance of their walls.* This phenomenon will be still more remarkable, if the capacity of these divisions, instead of being equal, is greatly superior to that of the trunk.

This last supposition is realized in the pulmonary artery, the capacity of which increases as it becomes divided and subdivided. It is evident, therefore, that the effects of the introduction of a quantity of blood into this artery, at each contraction of the right ventricle, must diminish as it is propagated, and at last cease altogether in the last divisions of the vessel. It must not be forgotten that the contraction of the right ventricle is the cause which keeps constantly in play the elasticity of the walls of the artery; that is, which distends them so as to overcome the constant tendency which they have to approach towards each other, and expel the blood. From this it will be perceived that there is,

* In order to understand this, it is necessary to recollect that the surfaces of circles are proportional to the squares of their circumferences. Thus, in the division of the canal into two branches, as we have supposed, if each circumference was only the half of the principal canal, the surfaces of each of the secondary canals would be but the fourth part of the surface of the primitive canal, and these two surfaces united would form but the half of this canal; in order that they should be equal, therefore, it is necessary that the circumferences of the two divisions, taken together, should exceed the circumference of the principal canal.

in fact, but one cause which gives motion to the blood in the pulmonary artery; this is the contraction of the ventricle; that of the artery being but the effect of the distention that it undergoes at the instant when a certain quantity of blood penetrates into its cavity, being forced there by the ventricle.

Authors have thought that they perceived in the contractions of the pulmonary artery, something analogous to that of the muscles. But when irritated with the point of an instrument, or caustics, or when submitted to the influence of a galvanic current, no motion analogous to muscular contraction has ever been observed. We must, therefore, consider this contraction as an effect of the elasticity of the walls of the vessel. In order to estimate the importance of the elasticity of the walls of the artery, let us suppose, for an instant, that, with its dimensions and ordinary form, it became an inflexible canal; immediately the course of the blood would be completely changed. Instead of traversing the lungs in a continued stream, it would only enter the pulmonary veins at the moment that it was propelled forward by the ventricle; at the same time it will be necessary to suppose that the artery would be always perfectly filled with blood; for if it were otherwise, it would be required that the ventricle should contract itself frequently before the blood would be made to pass into the lungs. Instead of this, observe what really takes place: the ventricle ceases for some moments to send blood into the artery; the course of the blood in the lungs nevertheless continues, as the artery contracts in proportion as it is emptied, and it requires that the time of emptying itself completely should be passed over before the course of the blood into the lungs is completely stopped; now this suspension can never take place during life. The passage of the blood through the lungs is necessarily continued, and nearly equally rapid, whatever may be the quantity of blood thrown into the pulmonary artery at each contraction of the ventricle.

Various attempts have been made to determine the quantity of blood thrown into the pulmonary artery at each contraction of the ventricle. In general, the estimate of its capacity has been formed on the supposition that all the blood it contains at the moment of its contraction passes into the artery; the estimate has been considerable. From what has been said above, however, it will be perceived how inaccurate this calculation must be, inasmuch as only a part of the blood contained in the ventricle is thrown into the artery; and as it is impossible to know how much is thrown out, and how much remains, it is evident that all these calculations give but an imperfect idea of the truth. Besides, it is much more important to know the mechanism by which the blood passes from the ventricle into the artery, and its course in this vessel; the quantity of blood which passes in a given time, even if it were known, would not be a circumstance of much importance. The blood, in passing from the small vessels in which the pulmonary artery terminates, and entering into the ramifications of the pulmonary veins, becomes changed in its nature in consequence

of the contact of the air, and acquires the peculiar qualities of the arterial blood. It is this change in the properties of the blood which essentially constitutes the function of respiration.

CHAPTER XVI.

ON RESPIRATION, OR THE TRANSFORMATION OF VENOUS INTO ARTERIAL BLOOD.

It is an indispensable condition to our continued existence, that the blood should be constantly brought in contact with the air through a medium bearing a certain proportion in its extent to the superficies of the whole body. During this contact the air takes away from the blood certain of its elements, and, reciprocally, the blood seizes upon certain elements of the air. This constitutes *respiration*, or the transformation of venous into arterial blood. Some authors attach a different idea to respiration; it is often defined the introduction and discharge of air from the lungs, but this double motion may take place without the function of respiration being performed. Others have thought that it consisted in the passage of the blood through the lungs, but it often occurs that this is effected without respiration. To study successfully this function, we must have an exact knowledge of the structure of the lungs, and precise notions of the chemical and physical properties of the atmospheric air; we must also understand by what mechanism the air is made to penetrate into and pass out from the chest. When we have described each of these points, we shall then consider the phenomenon of the transformation of venous into arterial blood.

Of the Lungs.

In the structure of the lungs, nature has resolved a mechanical problem of extreme difficulty. It has established an immense surface for the contact of the air with the blood in the very inconsiderable space which the lungs occupy. This admirable contrivance consists in an arrangement by which the minute vessels constituting the terminations of the pulmonary arteries, and the commencement of the pulmonary veins, are surrounded on all sides by air. Now the sum of the superficies of the walls of all the capillaries of the lungs would be an extremely extensive surface. Here the blood is only separated from the air by the thin walls of the vessels in which it is contained. If these walls were impermeable, as they would be if they were metallic plates, for example, the proximity of the air would be unavailable, and no chemical reaction of the two bodies upon each other would take place. But all the membranes, particularly those that are very thin, are

readily permeable to the gases, and even liquids, if they are not very viscid. Thus the walls of the pulmonary capillaries, though of sufficient thickness to retain all the viscid parts of the blood, offer but a slight obstacle to the passage of gas or the serosity of the blood. They are also readily traversed by the liquids or vapours which are accidentally introduced into the lungs.

It is not necessary to suppose, however, that the lungs, as regards respiration, possess special properties distinct from all the other organs; for all the small vessels which contain venous blood, and which are in contact with the air, become the seat of the phenomenon of respiration. The lung is only much better arranged than any other organ for the production of this phenomenon.

As respects their anatomy, the lungs are two spongy and vascular organs of considerable volume, situated on each side of the chest; their parenchyma is divided and subdivided into lobes and cells, the number, form, and dimensions of which are difficult to determine. From an attentive examination of a pulmonary cell, we learn that it is formed of a spongy tissue, the spaces of which are so small that it requires a glass of strong magnifying powers to see them distinctly; these areoles communicate with each other, and are enveloped by a delicate cellular tissue, which separates them from the neighbouring cells. A portion of the bronchiæ and pulmonary artery terminate about each of the cells. The artery is distributed about the tissue of the cells, but in a manner which is not known; it appears to terminate in an infinite number of minute ramifications in the pulmonary veins. I am myself disposed to believe that these numerous small vessels in which the pulmonary artery terminates, and the veins commence, by crossing and anastomosing with each other in different ways, form the areoles.* The small divisions of the bronchiæ which end about the cells do not penetrate into their interior, but finish suddenly when they arrive at the parenchyma.

This last circumstance appears to me remarkable, for inasmuch as the bronchiæ do not penetrate into the spongy tissue of the lungs, it is improbable that the surface of the cells with which the air is in contact is covered by the mucous membrane. Minute anatomy, at least, cannot demonstrate its existence in this place.

A part of the eighth pair of nerves, and some filaments of the sympathetic, are distributed to the lungs, but we do not know precisely how they are arranged. The external surface of the organ is covered by the pleura, a serous membrane analogous to the peritoneum both in structure and functions. About the bronchiæ, and near the place where they enter into the tissue of the lungs, there are a certain number of lymphatic glands, the colour of which is nearly black, and about which a small number of lymphatic vessels, which arise deep in the pulmonary tissue, terminate.

The art of fine injections furnishes us with some information relative to the lungs, which must not be omitted. If we force an

* This arrangement exists, more evidently, in the lungs of reptiles

injection of mercury, or simply of coloured water, into the pulmonary artery, the substance injected will pass into the pulmonary veins, and, at the same time, a part will penetrate into the bronchiæ, and pass out by the trachea. If the injection be made into the pulmonary veins, it passes into the pulmonary artery, and in part into the bronchiæ. Again, if the injection be introduced through the trachea, we shall find that it penetrates into both the pulmonary artery and veins, and even into the bronchial artery and vein. The lungs fill a great part of the cavity of the chest, enlarging and contracting with it; and as they communicate with the atmosphere by the trachea and larynx every time that the chest is enlarged, they are distended by the air, which is again expelled when the chest returns to its former dimensions. It is necessary, therefore, to stop a moment to examine this cavity. The chest or thorax is of a conoidal form, the apex of which is above, and the base below; posteriorly, it is formed by the dorsal vertebræ; anteriorly, by the sternum; and laterally, by the ribs; these last are twelve on each side, and are distinguished into true and false. There are seven of the first, and five of the last. The true ribs are above; they are articulated posteriorly with the vertebræ; anteriorly they are articulated with the sternum, by means of a prolongation called the cartilages of the ribs. It is the length, disposition, and motion of the ribs upon the vertebræ, which determine the form and dimensions of the chest.

The same muscle which, as we have already seen, constitutes the superior wall of the abdomen, forms also the inferior wall of the thorax. It is attached, at its circumference, to the lower part of the chest; but its centre is elevated towards this cavity, and forms, when it is in a state of relaxation, an arch, the middle part of which is on a level with the inferior extremity of the sternum. Thus the cavity of the thorax is divided into two portions, a superior, or thoracic, and an inferior, or abdominal portion. In the first, indeed, the thoracic organs, such as the heart, lungs, &c., only are lodged. The second contains the liver, spleen, and stomach. Numerous muscles are attached to the bones which form the outline of the thorax; of these muscles, some are intended to render the ribs less oblique upon the vertebral column, or to enlarge the capacity of the chest; others depress the ribs, render them more oblique upon the vertebræ, and diminish thus the capacity of the chest.

It will be proper for us to investigate the mechanism by which the chest enlarges or contracts itself, many of the phenomena of respiration being immediately connected with these variations of capacity. The chest may be dilated vertically, transversely, and from before backward; that is to say, in the directions of its principal diameters. The principal, or, to speak more correctly, the only agent of its vertical dilatation, is the diaphragm, which, in contracting itself, has a tendency to lose its arched form, and to become a plane; a motion which cannot be effected without the thoracic portion of the chest being increased, and the abdominal

diminished. The sides of this muscle being fleshy, and corresponding to the lungs, descends more than the centre, which, being aponeurotic, is incapable of making any effort of itself, and is also retained by its attachment to the sternum, and its union with the pericardium. In most cases, this depression of the diaphragm is sufficient for the dilatation of the chest; but it sometimes happens that the sternum and ribs, by changing the relation between them and the vertebral column, produce a sensible augmentation of the cavity of the thorax.

Nothing is easier to conceive than the mechanism of this motion when the physical arrangements of the part are well understood. It has, however, been a subject which has been discussed with great animation by some distinguished authors, who have, perhaps, given an importance to this question which it does not merit. If such controversies led to truth, we should not regret the time which the learned have devoted to them; but it is rare that this is the result; at least, it has not happened as respects the mechanism of the dilatation of the thorax. After a great number of discussions and experiments apparently accurate, Haller's opinions, which appear to me far from satisfactory, have prevailed. I will explain myself upon this point with all the deference which so high an authority demands.

His explanation of the dilatation of the thorax, now generally admitted, reposes upon bases which I cannot admit. He assumes that the first rib is nearly immovable,* and that the thorax is incapable of any motion, as a whole, either above or below.† It is difficult to imagine how so acute an observer as Haller should have advanced and supported such an idea; for we have only to examine upon ourselves the motions of respiration in order to see that the sternum and first rib are elevated during inspiration, and depressed in expiration. The examination of the recent subject affords the same result; we have only to press the sternum superiorly, and it will be found, with all the sternal ribs, to yield; the first moves upon the vertebral column, and the thorax is considerably enlarged.

After having assumed that the first rib is nearly immovable, Haller asserts that the second possesses five or six times more motion than the first; that the third is greater than the second; and that their mobility increases as you approach towards the lower ribs. With respect to the true ribs, the only ones which we are at present considering, I believe the fact to be directly the reverse of that advanced by Haller; that is, that the first rib is more movable than the second; this, again, than the third; and so on until you arrive at the seventh. But to judge accurately of the degree of mobility of the ribs, we must not confine ourselves to

* Primum par (costarum) firmissimum est, inde ut quæque inferiori loco ponitur, ita facilius emovetur, donec infima mobilissima fluctuet.—HALLER, *Elementa Physiologiæ*, tom. iii., p. 59, lib. viii.

† Totum tamen pectus, ut nunquam elevari vidi, ita nunquam deprimi.—HALLER, *loc. cit.*

observing, at their extremities, the motions they execute. For as they are of unequal lengths, a slight motion in the articulation, when the rib is long, will appear very great in its extremity; in the same way an extensive motion in the articulation of a short rib would appear trifling, if examined at its extremity. It is necessary, therefore, in cosidering the motion of the ribs, to suppose them all of an equal length; if this be done, it will then be evident that their mobility diminishes from the first towards the seventh, the last being nearly immovable.

The anatomical arrangement of the posterior articulations occasions this difference of mobility. The first rib has but one articulating facette at its head, and is only attached to one vertebra; it has no internal ligament, nor any costo-transverse ligament. The posterior ligament of the joint, with the transverse apophysis, is horizontal, and cannot obstruct either the elevation or depression of the rib.

None of these circumstances, which are so favourable to motion, are found to exist about the other ribs; they have each two articulating facettes at their head, and are articulated with two vertebræ. They have an internal ligament in the articulation, which prevents a gliding motion; a costo-transverse ligament attached to the superior transverse apophysis, which prevents the rib from decending; a posterior ligament directed from below upward is seen behind the articulation of the tuberosity, and prevents the rib from rising. Different shades in the disposition of these different ligaments permit the various degrees of mobility of which we have spoken. Besides, it is evident that a less degree of mobility existing in the long ribs, this is made up by the circumstance of their length, by which they are enabled to execute as extensive motions as the first, although they are less movable; for the same reason, it is quite possible that they may exhibit even a greater extent of motion. This compensation is indispensable, as the true ribs, their cartilages, and the sternum can only move together, and the motion of one of these pieces must, therefore, follow that of all the rest. It would follow, then, that if the inferior ribs were the most movable, they would be incapable of executing a greater extent of motion than that of the superior; and the solidity of the thorax would be diminished without any advantage to its mobility.

In most subjects, and frequently even in advanced age, the sternum is composed of two pieces, articulated by a movable symphisis on a level with the cartilage of the second rib. This arrangement, by permitting the superior extremity of the inferior piece to project a little forward, assists in enlarging the chest in a manner which I think has never been remarked.

But what are the muscles that elevate the sternum and ribs, and, of consequence, dilate the chest? According to Haller, the intercostal muscles are the principal agents of this elevation. The first intercostals, he remarks, find a fixed point in the first rib, which is immovable, and elevate the second; and all the in-

tercostal muscles successively taking the superior rib as their fixed point, elevate the inferior. But we have just seen that the first rib is far from being immovable; the explanation of Haller, therefore, necessarily falls to the ground; nor can I believe that the internal and external intercostals, whatever may have been said to the contrary, could produce the elevation of the ribs. The muscles which appear to me to be destined to this purpose are those which, having one extremity mediately or immediately attached to the vertebral column, the head, or superior extremities, can act directly or indirectly upon the thorax so as to elevate it. Among these muscles I will cite the anterior and posterior scaleni muscles, the muscles of the neck which are attached to the sternum, &c. I will also add another muscle, to which no one has ever attributed this use; I allude to the diaphragm. This muscle, indeed, is attached, at its circumference, to the inferior extremity of the sternum, the seventh true, and all the false ribs; when it contracts, it forces down the abdominal viscera, but, in order to do this, the sternum and ribs must present a resistance sufficient to counteract the effort made in the opposite direction. Now this resistance can be but imperfect, inasmuch as all these parts are movable; for this reason, every time that the diaphragm contracts, it must elevate the thorax more or less. In general, the extent of the elevation will be in direct proportion to the resistance of the abdominal viscera, and the mobility of the ribs.

There is another cause of the dilatation of the thorax, to which little attention has been heretofore given, but which appears to me to be very important. I refer to the pressure of the atmospheric air, which is exerted over the whole interior surface of the cavity, through the medium of the lungs. This pressure has such an influence, that if, by any cause, it ceases, the chest no longer dilates. The action of the elevator muscles on the ribs and the contraction of the diaphragm are ineffectual, if the thorax be not pressed upon internally by the atmospheric air. This phenomenon is very remarkable in certain affections, as pneumonitis, œdema, and emphysema of the lungs, &c. Sometimes this occurs in the whole of one side of the thorax, and partly the opposite side; at others it is confined to three or four ribs on one side, the other ribs of the same side continuing to move. It is certain that the atmospheric pressure is much concerned in the dilatation of the thorax, inasmuch as, if it ceases to act for a certain time, the side which is deprived of it becomes contracted, occasioning a great change in the general conformation of the thorax. Another proof of this that may be mentioned is, the facility with which the chest may be dilated by blowing into the trachea in the dead body, and the difficulty experienced if we endeavour to dilate it by elevating the ribs and sternum.

It is not indispensable that this pressure should be exerted through the medium of the lungs, as is proved by the following experiment. Close with a ligature the trachea of an animal; it will immediately make impotent efforts to dilate the cavity of the

chest. Make then an opening in one of the intercostal spaces, when the air will immediately force itself into the open side of the chest, which will enlarge at each inspiration. Make an opening now on the opposite side, and you will observe the same effect. It will be remarked that the elevation of the ribs is more easy and complete than in ordinary respiration. The reason is sufficiently obvious: the pressure of the atmosphere is not through the medium of the lung, but directly upon the parts which it concurs in moving.

In the general elevation of the thorax, the form of this cavity, and the relations of the bones which compose it, are necessarily altered. The cartilages of the ribs appear to be peculiarly adapted to this purpose. As soon as they become ossified, and, of consequence, lose their elasticity, the chest becomes immovable. At the same time that the sternum is carried superiorly, its inferior extremity is directed a little anteriorly; it experiences thus a slight oscillatory motion; the ribs become less oblique to the vertebral column; and they separate a little the one from the other, the inferior edge being directed outward, in consequence of a slight inflexion which the cartilage undergoes. All these phenomena can only be distinctly observed in the superior ribs; they are scarcely perceptible in the inferior.

To judge accurately of the mechanism of inspiration, it is necessary to study it in a person much emaciated, and under the age of thirty years. All the phenomena I have described will be visible, but will become much more apparent if the individual be attacked with difficulty of respiration. Then all the forces which elevate the throat will appear in full action; the scaleni muscles will swell at each inspiration, and relax at every expiration. With respect to the intercostal muscles in laborious respiration, sometimes they contract at the moment of inspiration, and sometimes, on the contrary, they relax when there is a remarkable depression in each intercostal space.

There results from the elevation of the thorax a general enlargement of this cavity, both from before, backward, laterally, and from above downward. This enlargement is called inspiration; it exhibits three well-marked degrees. First, *ordinary inspiration*, which is made by the depression of the diaphragm, and an almost insensible elevation of the thorax. Second, *a deep inspiration*, in which the elevation of the thorax is evident, at the same time that the diaphragm is depressed. Third, *forced inspiration*, in which the dimensions of the thorax are augmented in every direction that the physical disposition of this cavity will permit. In the first degree of inspiration, the air only penetrates into a limited portion of the lung; in the second, there is still more; but it is only in the third degree, *forced inspiration*, that it is introduced through the whole extent of the lung. This last mode of inspiration should be executed by the patient when we study the state of the respiratory organs. To the dilatation of the thorax succeeds expiration; that is, the return of the thorax to its

ordinary position and dimensions. The mechanism of this motion is precisely the reverse of that which we just described. It is produced by the elasticity of the cartilages and ligaments of the ribs, which tend to react upon themselves, when the relaxation of those muscles which elevated the thorax permit it, and, finally, by the contraction of a great number of muscles, so disposed that they depress the thorax and draw it back. Among these muscles, which are very numerous and very strong, it is proper to mention the large muscles of the abdomen, the great dorsal, the sacro-lumbalis, and the serratus posticus inferior, &c.

The contraction of the thorax, or expiration, presents also three degrees: first, ordinary expiration; second, deep expiration; third, forced expiration. In ordinary expiration, the diaphragm, being relaxed, is crowded up by the abdominal viscera, which are pressed by the anterior muscles of this cavity, and cause a diminution of the vertical diameter of the thorax. The relaxation of the inspiratory, and a slight contraction of the expiratory muscles, permit the ribs and sternum to resume their ordinary relation to the vertebral column, and thus produce a strong expiration. But the retraction of the chest may go still farther than this. If the abdominal and other expiratory muscles contract forcibly, there will result from this a more remarkable crowding up of the diaphragm, a much greater depression of the ribs, and a much stronger contraction of the base of the chest, and, of consequence, a considerable diminution of the capacity of the thorax. This is called *forced expiration.*

To comprehend how the lung dilates and contracts with the thorax, Mayo compared the lung to a bladder on the interior of a bellows, which communicated with the external air through the tube of the instrument. This comparison, just in many respects, is inaccurate in one very important point of view. The bladder is an inert membrane, which suffers itself to be distended by the pressure of the air, but which does not return upon itself except by the compression of the walls of the bellows. The lung is in a very different condition; it is continually disposed to return upon itself, and to occupy a less space than the cavity it fills. It exerts, then, a traction at all points of the walls of the thorax. Thus traction has little influence upon the ribs, which cannot yield, but has a great influence upon the diaphragm. This muscle is always constantly drawn up by it so as to form an arch. When this muscle is depressed by contracting upon itself, it draws the lungs towards the base of the chest; these organs are more and more distended, and, in consequence of their elasticity, they are disposed to react upon themselves, and to draw up the diaphragm with proportionate energy. The diaphragm, indeed, would be suddenly drawn back in the form of an arch as soon as it ceased to contract, if it were not for a particular movement of the glottis, of which we shall speak below, and which opposes some obstruction to the sudden discharge of the air from the thorax. The ascension of the diaphragm in expiration is also favoured by the elas-

ticity or even contraction of the abdominal muscles, which have been distended by the crowding down of the viscera at the moment of the contraction of the diaphragm.

To judge of this reciprocal action of the diaphragm and lung, it is necessary to lay bare the intercostal muscles on one side of the chest in a young animal, and see, through these muscles, the lung and diaphragm rise and descend together, without there being any perceptible interval between them. We can also see that the lung is always in contact with the walls of the thorax, and that they glide upon these walls in their different movements. It is also easy to remark that, during expiration, a great extent of the superior face of the diaphragm is applied to the walls of the thorax, and occupies the space that the lung filled during inspiration.

Of the Air.

The earth is surrounded on every side by a very thin and transparent fluid called the air, the whole mass of which is called the atmosphere. It extends from the surface of the earth to a height of about fifteen or sixteen leagues. The air is an elastic fluid; that is, it possesses in itself the property of exercising a pressure upon those bodies which it surrounds, and upon the walls of those vessels which contain it. This property supposes, in the particles of which the air is composed, a constant tendency to repel each other. Another property of the air is *compressibility;* that is, its volume changes according to the pressure to which it is submitted. Experiment informs us that the same mass of air, when subjected successively to different degrees of pressure, occupies spaces or volumes which are in an inverse ratio to the degrees of pressure; so that the pressure becoming double, triple, or quadruple, the volume is reduced one half, one third, or one fourth.

In the atmosphere, the pressure that any given mass of air supports is in proportion to the weight of those strata which are above it; its weight and density, therefore, diminish as we rise from the earth. At the surface of the earth the pressure of the atmosphere is the result of its total weight. This pressure is capable of sustaining a column of mercury thirty-two inches high; the instrument employed for this purpose is called a barometer. Different physical circumstances cause a slight variation in the atmospheric pressure. It is, for example, weaker at the summit of mountains than in valleys; it is greater when the air is charged with humidity than when it is dry. These variations may be very accurately appreciated by means of a barometer.

Like all other bodies, the air is dilated by heat; its volume augments 1.266 for every degree of heat of the centigrade thermometer. The air is heavy; this we may satisfy ourselves of by weighing at first a balloon filled with air, and weighing it afterward, when it has been emptied by means of an airpump. It has been found in this way, the temperature being at 0, and when

the barometer was raised to thirty inches, that sixteen cubic inches of air weighs 19 grains; the same volume of water weighed 2 pounds, 3 oz., 5 dr. Water is, therefore, 770 times heavier than air.

The atmosphere is more or less charged with humidity; this arises from the continual evaporation of those waters which cover the surface of the earth. We find, from experiment, that water is changed into vapour at all temperatures, but this takes place most rapidly when the temperature is highest. Farther, the air can only contain a certain quantity of vapour at a given temperature; when it is saturated the humidity is extreme. The nearer it approaches this state the greater is the humidity; the instruments which indicate the humidity of the air are called hygrometers. When, in consequence of cooling, or any other cause, the air is incapable of containing all the vapour which it before possessed, this excess assumes the form of mist or clouds, or is precipitated in the form of rain, or snow, &c. The vapour of water being lighter than air, and causing it to become dilated when it is mixed with it, the result is, that humid is much lighter than dry air.

Notwithstanding its thinness and transparency, the air refracts, intercepts, and reflects light. In a small mass, we see too few rays to have its colour produce a sensible impression upon our eyes; in a large mass, the colour is very distinctly blue. The interposition of large masses of air gives also a bluish tint to distant objects. The air is of great importance in chemical phenomena. It was regarded for a long time as an element; its composition was first suspected by John Ray in the seventeenth century, and was afterward fully established by Lavoisier. The air is composed of two gases, possessing very different properties. First. *Oxygen* is a little heavier than atmospheric air, and combines with all simple bodies; it is one of the elementary principles of water, and vegetable and animal substances; and of the greater parts of known bodies, it is necessary to combustion and respiration. Second. *Azote* is rather lighter than air, is one of the elements of ammonia and of animal substances, and extinguishes bodies in a state of combustion.

The proportions of oxygen and azote which enter into the composition of air are determined by means of instruments called eudiometers. In these instruments we produce the combination of oxygen with some combustible body, such as hydrogen or phosphorus, and the result of this combination makes us acquainted with the quantity of oxygen that the air contained. It is thus found that a hundred parts of air in weight contain 21 parts of oxygen and 78 of azote. The proportions are the same in all places and at all heights, and have not undergone any sensible change in the period which has elapsed since chemistry established this point in a positive manner. The air contains, besides oxygen, azote, and the vapour of water in a variable quantity, as we have already remarked, a very small quantity of carbonic

acid, the proportion of which is not fixed in a very rigorous manner. Nearly all combustible bodies decompose the air, at a temperature peculiar to each. In this decomposition, they combine with the oxygen, and leave the azote free.

Inspiration and Expiration.

The lungs are always filled with air, but this fluid is promptly altered by the act of respiration. It is therefore necessary that it should be frequently renewed; this is accomplished by the two phenomena of inspiration and expiration. In the first, the air is drawn into the lungs, distends them, and extends even to the extreme air-cells; during the second, a part of the air contained in the lungs is driven out. In these two physical acts the atmospheric pressure and the muscular contraction are the principal agents.

If we examine the chest after an ordinary expiration, we see that the air which presses upon its external surface is exactly in equilibrio with that which presses upon the internal surface of the lung. The pressure of the latter occurs through the medium of the column of air in the cavity of the mouth and nasal passages, the pharynx, larynx, trachea, and bronchiæ. The least effort of the powers which dilate or contract the thorax will be sufficient to cause the air either to penetrate into the lungs, or expel it. The mechanism of respiration is therefore easy; as soon as the dilating muscles of the thorax act, immediately the external air is precipitated into the glottis, the trachea and the lungs are filled, as the tendency to a vacuum is produced by the enlargement of the chest.

We may here make a few remarks in explanation of the hardness and elasticity of the walls of the passage through which the air passes to arrive at the air-cells of the lungs. Let us suppose, for a moment, that the walls of the trachea or larynx had been membranous instead of cartilaginous; then, at the moment of the dilatation of the thorax, the air, which presses equally on all points of the surface of the body, would close up the aërial passages about the neck, and the air could not penetrate into the thorax. But the walls of the mouth, nose, and larynx, and the rings of the trachea, resist the pressure of the air, which can only act upon the internal surface of the air-passages.

There is such a relation between the pressure of the atmosphere and the cartilaginous aërial passages, that where there is no pressure, as on the posterior part of the trachea and the small bronchial divisions, there is no cartilaginous structure.

If we recollect the disposition of the pulmonary cells, the extensibility of their tissue, their communication with the external air by means of the bronchiæ, the trachea, and the larynx, we shall be easily able to conceive that every time the chest is dilated the air rushes into the lungs in a quantity proportioned to the degree of dilatation. When the chest contracts itself, a part of the air contained in it is expelled, and rushes out through the glottis. In

order that the air may arrive at the glottis in inspiration, or pass out from it in expiration, it will sometimes traverse the nasal fossæ, and sometimes the mouth; the position that the veil of the palate assumes on these occasions deserves attention. When the air traverses the nasal fossæ and the pharynx, to enter into the larynx, or to pass out from it, the veil of the palate is vertical, and applied to the anterior surface of the posterior part of the base of the tongue, so that the mouth has no communication with the pharynx. When the air traverses the mouth, in inspiration or expiration, the veil of the palate is horizontal, its posterior edge embraces the concave surface of the pharynx, and all communication is stopped between the inferior part of the pharynx and the superior part of this canal, as well as the nasal fossæ. Hence the necessity of requesting patients to breathe through the mouth, if we wish to inspect the tonsils or the pharynx.

These two ways by which air arrives at the glottis are necessary, and occasionally supply each other's place. Thus, when the mouth is filled with aliment, the respiration is made through the nose; and it takes place through the mouth when the nasal fossæ are obstructed by mucus, a slight swelling of the pituitary membrane, or any other cause.

The glottis is by no means passive during inspiration and expiration. It opens and closes alternately. Its dilatation, which coincides with inspiration, favours the entrance of the air into the respiratory organs. The closing takes place at the moment that expiration begins, so that it always presents a certain obstacle to the expulsion of the air from the lungs, and its edges are always moved by the expired air. By completely closing the glottis we can entirely prevent the expulsion of the air, whatever may be the expiratory effort. In this case the small constrictor muscles of the glottis resist the immense powers concerned in expiration. Some diseases appear to consist principally in defective dilatation of the glottis during inspiration; the consequence is extreme dyspnœa, with the most violent efforts to drive the air into the lungs. I had a striking example of this in a child on whom I performed the operation of laryngotomy. I was led to believe that the suffocation arose from a false membrane that closed up the glottis. As soon as the operation was performed, the air entered the lungs freely through the wound, and the sense of imminent suffocation at once ceased, which proved that the obstacle was about the glottis. Still it was found without obstruction. I then attempted to close the wound, and make the child breathe through the larynx; but the suffocation immediately returned, so that I was compelled to keep the edges of the incision open for twenty-four hours by an assistant.

It appears that the number of inspirations made in a given time differs essentially in different individuals. Hale states that there were twenty in the space of a minute. A man upon whom Menzies experimented, breathed but fourteen times in a minute. Sir Humphrey Davy informs us that he respired twenty-six or twen-

ty-seven times in that space. Mr. Thompson says that his ordinary breathing is nineteen times in a minute; but I breathe myself fifteen times in the same period. Taking twenty, then, as the medium, we shall have 28,800 inspirations in twenty-four hours. But it is probable that this number will vary very much, from a variety of circumstances: such as the duration of sleep, motion, distention of the stomach by aliment, the capacity of the chest, and the moral affections.

What quantity of air, it may be inquired, enters into the chest at each inspiration? What quantity passes out at each expiration? And how much remains there habitually? According to Menzies, the medium quantity of air which enters into the lungs at each inspiration is three hundred and twenty cubic inches. Goodwin thinks that, after a complete expiration, the lungs still contain about eight hundred and eighty cubic inches. Menzies asserts that the quantity is much greater, and that it amounts to fourteen hundred and sixty-one cubic inches.

According to Davy, after one strong expiration, his lungs retain three hundred and thirty-two cubic inches.

After a natural expiration . . .	970	cub. in.
After a natural inspiration . . .	1106	"
After a strong inspiration . . .	3206	"
By strong expiration, after a deep inspiration, there passed out from the lungs .	1556	"
After a natural inspiration . . .	643	"
After a natural expiration . . .	353	"

Mr. Thompson thinks that we shall not be far from the truth if we suppose the quantity of air generally contained in the lungs to be 2294 cub. in., and that there enters and passes out of the chest, at each expiration and inspiration, 327 cub. in. Thus, supposing twenty inspirations in a minute, we should have entering and passing out from the lungs in this time 6500 cub. in.; and in twenty-four hours 75,556 cub. in., or nearly 48 pounds.

Chemists have made a great number of experiments to determine whether the volume of air diminishes during the time it remains in the lungs. The most recent experiments, those of Messrs. Dulong and Despretz, show the diminution to be considerable. M. Despretz, having caused six small rabbits to breathe in forty-nine pints of air, during two hours, found there was a diminution of one pint.

In traversing successively the mouth or nasal cavities, the pharynx, the larynx, the trachea, and the bronchiæ, the inspired air acquires a temperature nearly equal to that of the body. Having become heated, and, of consequence, rarefied, the same quantity of air in weight occupies a much greater space in the lungs than before it was introduced into this viscus. Besides this change in volume, the inspired air becomes loaded with the vapour which is continually thrown off from the mucous membrane of the lungs; it is therefore not only warm, but humid, when it

arrives at the pulmonary cells; finally, the portion of air of which we have spoken becomes mixed with that which the lungs before contained. But expiration soon succeeds inspiration; a few seconds ordinarily intervene; the air that the lungs contain, compressed by the expiratory powers, escapes in an inverse ratio to the air inspired. It is proper here to remark, that the portion of air expired is not identically that which had been just inspired, but is a portion of the mass which the lungs contained before inspiration. If we compare the volume of air that the lungs habitually contain with that inspired and expired at each respiration, we shall be induced to believe that the end of inspiration and expiration is but to renew, in part, the large mass of air contained in the lungs. This renewal will be much more considerable when the quantity of air expired is very great, and the succeeding inspiration strong.

Physical and Chemical Changes that the Air undergoes in the Lungs.

The air passes out from the lungs at about the same temperature with the body; a great quantity of vapour, called pulmonary transpiration, escapes with it; its chemical composition is different from that of the air inspired. The proportion of azote is nearly the same, but the quantity of oxygen and carbonic acid are essentially different. Instead of twenty-one parts of oxygen, and one of carbonic acid, in one hundred, which the atmospheric air presents, the expired air is found to contain eighteen or nineteen parts of oxygen and three or four of carbonic acid. In general, the quantity of carbonic acid is less than that of the oxygen that has disappeared. From the late experiments of Messrs. Dulong and Despretz, this difference is about one third in carnivorous animals, and only about one tenth in herbivorous. To estimate the quantity of oxygen consumed by an adult in twenty-four hours, it is only necessary to recollect the quantity of air respired during this interval. According to Lavoisier and Davy, two hundred and fifty-six cubic inches are consumed in one minute, which gives in twenty-four hours two thousand nine hundred and eighty cubic inches.

It is not difficult to appreciate the quantity of carbonic acid that passes out from the lungs at the same time, inasmuch as it is nearly equal to the volume of oxygen that has disappeared. Thompson estimated it at three hundred and twenty cubic inches; though it may be, he remarks, probably less. Now this quantity of carbonic acid represents about five thousand two hundred and seventy grains of carbon. Some chemists say that a small quantity of azote disappears during respiration; but this has not been confirmed by the most recent researches. Others have thought, on the contrary, that the quantity of this gas is sensibly augmented. This last result has been placed beyond doubt by the labours of Messrs. Edwards, Dulong, and Despretz, who have always found a decided increase of azote in the air when respired by animals

after a certain time. We are informed of the degree of alteration that the air undergoes in our lungs by a sensation which impels us to renew it. This is hardly perceptible in common respiration, because we hasten to obey this impulse; but it becomes extremely painful if this sensation be not satisfied; it soon causes anxiety and fear, which are instinctive evidences of the importance of respiration. While the air contained in the lungs is thus modified, both in its physical and chemical properties, the venous blood traverses the ramifications of the pulmonary artery, which form, in part, the tissue of the cells of the lungs. It then passes into the ramifications of the pulmonary veins, and soon into the veins themselves; during this, the nature of the blood becomes changed from venous to arterial blood. Let us now examine the phenomena of this transformation.

Change of the Venous into Arterial Blood.

At the moment when the blood passes through the minute vessels which cover the pulmonary or air cells, it assumes a bright scarlet colour; its odour is stronger, its taste more distinct, and its temperature elevated about one degree. One part of the serum escapes, in the form of vapour, into the air-cells, and mixes with the air. Its tendency to coagulate sensibly augments. This fact is generally expressed by saying its *plasticité* is much greater; its specific gravity, and its capacity for caloric, are both diminished. When the venous blood has acquired these characters, it becomes arterial. In order that we may render more evident the differences between arterial and venous blood, we shall recapitulate them in the following table:

Principal Differences between Venous and Arterial Blood.

	Venous Blood.	Arterial Blood.
Colour . . .	a modena red,	bright scarlet.
Odour	weak,	strong.
Temperature . .	98° Far.	nearly 100.
Capacity for caloric .	852,*	839.
Specific gravity . .	1051,*	1049.
Coagulation . .	less prompt,	more prompt.
Serum . . .	more abundant,	less abundant.

An analysis of the venous and arterial blood by Messrs. Macaire and Marcel has enabled them to point out a striking difference between these two liquids, especially as regards the quantity of oxygen and carbon that enters into their composition. The following is the result of their analysis made by the oxide of copper after having dried the blood in a vacuum by sulphuric acid, and reduced the arterial blood to a beautiful red powder, and the venous to a reddish brown.

	Arterial Blood.	Venous Blood.
Carbon	50.2	55.7
Azote	16.3	16.2
Hydrogen	6.6	6.4
Oxygen	26.3	21.7

* Water being as 1000.—J. Davy.

I have already described the changes that the air undergoes in the lungs, and am now about to notice those which take place in the venous blood in traversing these organs; let us now see what connexion exists between these two orders of phenomena. The colour of the blood evidently depends upon its mediate contact with the oxygen; for, if any other gas exists in the lungs, or if the atmospheric air be not renewed, this change in colour no longer takes place. But it manifests itself anew as soon as we permit the introduction of oxygen gas into the air-cells of the lungs. It is easy to see the phenomenon of the change in colour of the venous blood, even in the dead subject. At the approach of death, the venous blood often accumulates in the vessels of the lungs; the bronchiæ being deprived of air, it preserves the venous properties long after death. If the atmospheric air be forced into the trachea in such a manner as to distend the tissue of the lungs, it causes a change of colour in the blood, from the modena red to a bright vermilion tint.

The same phenomenon is observed whenever the venous blood is brought in contact with oxygen or atmospheric air. Blood drawn from a vein and exposed to the air assumes a brighter tint; immediate contact is not necessary; the same blood contained in a bladder, and plunged into oxygen gas, becomes scarlet over its whole surface. Thus the very delicate vascular walls which, in the lungs, separate the atmospheric air and the blood, cannot be considered as an obstacle to this change of colour. But it may be inquired, How does oxygen gas produce this change of colour in the venous blood? Chemists are not agreed upon this point. Some think that it combines directly with the blood; others, that it removes from the blood a certain quantity of carbon; and there are others, again, who are inclined to believe that both these effects take place; but neither of these explanations will satisfactorily account for the change of colour. Many chemists have attributed the peculiar colour of the blood to the presence of iron, but this opinion is now rejected as extremely doubtful; it will, however, seem less unreasonable, when it is recollected that if this metal be separated from the coloured part of the blood, it loses the property of becoming scarlet on being exposed to oxygen gas.*

We may easily imagine the loss of serum which the blood undergoes in respiration. It is very probable that a certain quantity of serum escapes from the extreme ramifications of the pulmonary artery, and evaporates into the air which the cells contain. This vapour afterward passes out with the expired air, under the denomination of pulmonary transpiration; but it does not necessarily follow that all the vapour which passes out from the blood during expiration arises from the pulmonary artery. I have remarked above, that a considerable portion of this vapour is thrown

* We must not confound the colouring matter of the blood described by Messrs. Brande and Vauquelin with *hæmatine*, the colouring matter of logwood, which was discovered by M. Chevreul.

off by the arterial blood, which is distributed to the mucous membrane of the bronchiæ. In his first researches upon respiration, Lavoisier believed that a combination of hydrogen and oxygen took place in the lungs, from which resulted the formation of a certain quantity of water; and that this water formed a part of the pulmonary transpiration. This idea, however, is not at present admitted; but this transpiration is considered as the result of the passage into the air-cells of a part of the fluid which passes through the pulmonary artery. Anatomy seems to confirm this; water injected into the pulmonary artery passes, under the form of innumerable small drops, almost imperceptible, into the air-cells, and mixes with the air which they contain.

In living animals we may increase at will the quantity of pulmonary transpiration, by injecting distilled water at, the temperature of the body, into the venous system, as the following experiment will prove. Take a small dog, and inject, at different times, a considerable volume of water; the animal will at first be in a perfect state of plethora; its vessels will be so completely distended, that it will move with difficulty; but, at the end of some moments, its respiration will become considerably accelerated, and there will be poured out a great abundance of fluid from the throat, the source of which is evidently the pulmonary transpiration considerably augmented. It is not only the aqueous part of the blood which escapes by pulmonary transpiration. I have shown, by direct experiments, that many substances introduced into the veins, either by absorption or direct injection, soon pass out by the lungs. Diluted alcohol, a solution of camphor, of æther, or odoriferous substances, introduced into the cavity of the peritoneum, or any other part, are soon absorbed by the veins, and, transported to the lungs, pass into the bronchiæ, and may be recognised by the peculiar odour of the expired air.

Phosphorus acts in the same manner; its odour is not only sensible in the expired air, but its presence is still more easily shown, and in the most positive manner. Inject into the crural vein of a dog half an ounce of oil, in which phosphorus has been dissolved; you will scarcely have performed this operation, when there will issue from the nostrils of the animal a dense white vapour, which is the phosphoric acid. It appears from the experiments of Dr. Nysten, that gases act in nearly the same manner; that is, that after they have been injected into the veins, they pass out with the expired air.

Some attempts have been made to determine the quantity of vapour that escapes from the lungs of an adult in twenty-four hours. The latest, performed by Mr. Thompson, fix it at about eighteen ounces; Lavoisier and Seguin formerly estimated it at something less than this. It is probable that it is varied by an infinite number of circumstances.

It is not yet considered as settled in what mode the carbonic acid contained in the expired air is formed. It is thought by some that it exists, ready formed, in the venous blood, and that

it is exhaled by this fluid at the moment of its passage through the lungs; by others, that it is the result of the direct combination of the carbon of the venous blood with the oxygen; but neither of these opinions can be considered as fully established; perhaps both these effects may take place at the same time. From our ignorance of the mode of formation of the carbonic acid, we are unable to fix the precise part performed by the oxygen in respiration. Some assert that it is employed to combine with the carbon of the venous blood; others, that it passes into the pulmonary veins; and there is still another class who believe that it performs both these offices at the same time. All this part of animal chemistry requires farther investigation; so long as we have not any positive knowledge concerning the formation of carbonic acid, and the disappearance of oxygen, it will be difficult to determine the cause of the elevation of temperature which takes place in the blood in passing through the lungs. It is probable, however, that the oxygen combines with the carbon of the blood, and, as every formation of this kind is accompanied by a considerable evolution of caloric, it is probable that this is the cause of the increased heat of the arterial blood. If we suppose, also, that the oxygen is absorbed, passes into the pulmonary veins, and that it combines afterward directly with the blood, we may then account for the elevation in the temperature of the blood; for every combination of oxygen with a combustible body is accompanied with an evolution of caloric.*

The slight diminution in the specific gravity of the blood, and its capacity for heat, arises probably from the loss of water from the surface of the air-cells. With respect to the other properties that the venous blood acquires in traversing the lungs, such as its odour, peculiarity of taste, &c., that our opinions on this point may be accurate, it is necessary that an exact and comparative analysis of the venous and arterial blood should make us precisely acquainted with these differences. This is a service for which physiology looks to the science of chemistry.

Respiration of other Gases than Atmospheric Air.

We must not rest satisfied with studying the effects of the respiration of atmospheric air; we are naturally desirous of knowing what would be the result of the respiration of other kinds of gas. Animals have been plunged into them, and men have voluntarily or involuntarily respired them; it is thus known that atmospheric air alone can serve the purposes of respiration for any considerable time. Every other gas destroys animal life more or less promptly; oxygen itself, when respired pure, is fatal, and even when it is mixed with azote in proportions different from the common air, it sooner or later causes the death of those animals that respire it. From these facts we are induced to divide gases, as they relate to respiration, into two classes: first, those which are non-respirable; second, those that are deleterious.

* See article *Animal Heat.*

The first, to which belong the protoxide of azote, hydrogen, &c., destroys animals only because they are incapable of fulfilling the office of oxygen. Among these gases there is one, the protoxide of azote or nitrous oxide, which produces very remarkable effects, and which may perhaps be considered as belonging to the second class. Sir H. Davy was the first who examined the effects of this upon himself. After having expired the air from his lungs, he breathed about five pounds of the protoxide of nitrogen; the first sensations which he experienced were those of vertigo; at the end of about half a minute, continuing still to respire this air, these effects gradually diminished, and were succeeded by a sensation analogous to a gentle pressure over all the muscles, accompanied by a slight, but very agreeable trembling, particularly in the chest and extremities. Surrounding objects appeared to him of a dazzling brightness, and his hearing to become more acute; towards the last, the agitation augmented, his muscular force seemed much increased, and he felt an irresistible propensity to put himself in motion. These effects diminished as soon as he had ceased to respire the gas, and in the course of ten minutes he found himself as usual.

The effects are not, however, always the same; Vauquelin and Thenard, who also respired this gas, did not perceive all the phenomena described by Davy, but others analogous to them. The deleterious gases are those which are not only incapable of respiration, but destroy, more or less rapidly, men and animals which respire them, even when mixed with certain portions of atmospheric air. Of this number are all the acid gases, ammoniacal gas, sulphuretted hydrogen, &c., &c.

Influence of the Nerves of the Eighth Pair upon Respiration.

The nerves of the eighth pair are the only cerebral nerves which send filaments to the tissue of the lungs; this has induced physiologists to divide them, to ascertain the effects that would result from it. This easy experiment was made often by the older physiologists, and there are few of the modern who have not repeated it. Every animal in which the nerves in question are divided dies more or less suddenly; sometimes death takes place instantly after the division. It never survives more than three or four days. Death has been attributed by authors, in turn, to the cessation of the motions of the heart, imperfect digestion, inflammation of the lungs, &c. We are indebted to the labours of many physiologists, and especially to Messrs. Wilson, Philip, and Breschet, for some valuable information on this subject. I now propose to give an abstract of their researches and my own.

A division of the nerves of the eighth pair, in the neck, on a level with the thyroid gland, or even lower, has an influence, first, upon the larynx; second, upon the lungs. These two classes of effects must be distinguished. In treating of the voice, we have said that the division of the recurrent nerves produced a sudden loss of the voice. The same phenomenon takes place after the

division of the eighth pair of nerves, which is easy to understand, as the recurrents are but branches of these nerves. But, besides the loss of the voice, it is not uncommon for a section of the nerves of the eighth pair to be followed by such an approximation of the lips of the glottis, that the air is incapable of penetrating into the larynx, and that sudden death happens; as is always the case in an animal which is incapable of renewing the air of its lungs. In ordinary cases, the sides of the glottis are not brought so exactly in contact as to entirely prevent the air from entering into the larynx for the purposes of respiration. But, as the glottis has lost its peculiar motion, the air enters into, and passes out from the chest, in a more irregular and constrained manner.

At the time when these observations were made, it would have been impossible to have explained satisfactorily these different phenomena. But as the reader is now acquainted with the manner in which the recurrent and laryngeal nerves are distributed to the muscles of the larynx, the subject presents no farther difficulty. By the division of the eighth pair at the lower part of the neck, the dilator muscles of the glottis are paralyzed. This opening no longer enlarges itself at the instant of inspiration, while the constrictors, which receive their nerves from the superior laryngeal, preserve their action, and close the glottis more or less completely. When the section of the eighth pair is not followed by such a constriction of the glottis as to cause instantaneous death, other phenomena are developed, and death does not occur until the end of three or four days.

Respiration is at first constrained, the motion of inspiration is more extensive and frequent, and the animal seems to pay a particular attention to it; he is not inclined to move, is evidently fatigued by exertion, and will often preserve a perfect state of repose. The formation of arterial blood is not prevented for a short time after the operation; but soon, the second day, for example, the laborious respiration increases, and the efforts in inspiration become greater. The arterial blood has no longer the vermilion tint which is peculiar to it; it becomes deeper coloured, and its temperature diminished; at last all these symptoms increase; respiration can only be effected by the action of all the inspiratory muscles; the arterial blood becomes of a dull red, and similar to venous blood; the arteries containing but little of it, a chilliness becomes manifest, and the animal soon dies. On opening the chest we find the bronchiæ, and sometimes the trachea itself, filled with a frothy fluid, sometimes bloody; the tissue of the lungs is engorged and swollen; the ramifications, and even the trunk, of the pulmonary artery, are distended with blood of nearly a black colour; there is likewise found a considerable effusion of serosity, or even of blood, into the parenchyma of the lungs. On the other hand, experiments show that, in proportion as this series of phenomena becomes developed, the animals consume less oxygen, and form a less quantity of carbonic acid. It has been supposed, with reason, that in this case the animals perish be-

cause respiration cannot be performed, the structure of the lungs being so altered that the inspired air cannot arrive at the air-cells. I think we may add to this cause the difficulty which the blood from the pulmonary artery experiences in passing into the vein; a difficulty which appears to me to be the cause of the distention of the venous system after death, and of the small quantity of blood which the arterial system contains some time before this event happens.

The section of one of the nerves of the eighth pair produces these effects upon one of the lungs only, and life may be continued by the action of the other of these organs, the animal not perishing. I have seen animals live in this state many months.

Many authors, worthy of confidence, have stated facts respecting the division of these nerves that I have not been able to verify. If we allow an interval of a month or two, say they, between the division of one nerve and that of the second, the animal survives, a union taking place between the divided ends, and that cicatrix transmits the nervous influence like the nerve itself. Cut this cicatrix, divide the nerve a second time, and at the same moment the effects of the simultaneous section of the two nerves will become manifest. I will not pretend to deny these results, but I have endeavoured to repeat them without success. I have cut, in dogs, the eighth pair on one side; three months after I have cut that of the opposite side; the animals died three or four days after the last operation. At the opening, after death, I have found the lung on the side on which the first nerve was cut so changed in its structure that it was incapable of the function of respiration. Hence the division of the second nerve necessarily caused death.

According to some physiologists, the simple division of the eighth pair differs much, as respects the results, from a section where a certain portion of the nerve is cut away so as to leave a considerable interval between the divided ends. In general, say they, the effects are much more striking, and the animals die much sooner. It is the same if, instead of cutting off a portion of the nerve, we fold away one of the ends so that it shall be remote from the other. Lastly, here, as in indigestion, it is said that a galvanic current takes the place of nervous influence. My experiments do not agree with these results.

I have never seen any difference, as regards the results, between the simple division of a nerve or cutting off a portion. I have never obtained anything, in these circumstances, from the galvanic action.

Of Artificial Respiration.

The principal object of the motion of the thorax is to draw air into the lungs, and afterward to expel it from these organs. Whenever these motions are stopped, the air of the lungs being no longer renewed, respiration necessarily ceases, and death soon follows. But we may supply, for a certain time, the action of

the thorax, by introducing air artificially into the lungs. Both ancient and modern anatomists have often practised this. The air has been gradually introduced with bellows, or bladders, &c. This may also be done with a syringe, with a small hole on the side of its tube. The end of the tube is introduced into the trachea, and fixed there by a ligature; afterward we draw the piston, in order to fill the syringe with air; we then apply one finger upon this small hole, to prevent the air from passing out through it; the piston is then forced down, and the air of the syringe passes into the lungs. We then withdraw the piston, and the syringe becomes filled with air from the lungs; we now raise the finger placed upon the small hole, and, by pushing down the piston, cause the air to escape, which has already performed the purposes of respiration; we draw immediately the piston, to fill the instrument with pure air, leaving the little hole open, &c. By repeating regularly these motions, we are enabled to protract the life of an animal, in which the thorax has become immovable, either from a division of the spinal marrow behind the occipital bone, or even where the head has been entirely cut off. It, however, fulfils but very imperfectly the function of respiration, and can never be prolonged beyond a few hours. Frequently the lungs become engorged by the blood, or are torn by the air; this fluid is also introduced into the pulmonary veins, and spreads itself into the cellular tissue, so as to prevent the dilatation of the air-cells. In inflating the lungs, great care is necessary not to force the air so as to tear the pulmonary tissue. If the air pass into the cavity of the pleura, the animal will die immediately, as occurred in the curious experiments of M. Leroy d'Etiole.

CHAPTER XVII.

COURSE OF THE ARTERIAL BLOOD.

This function has for its object to transport the arterial blood from the lungs to every part of the body.

Of the Arterial Blood.

The arterial blood is essential to the execution of the functions. A celebrated physiologist defined *life* as the contact of the arterial blood with the organs, particularly the brain. We have nothing to add here to what has been already said of the arterial blood in the article *Respiration.* I will only refer to some important facts relative to the blood generally, which will complete the history of this liquid.

The learned Vauquelin found in this fluid a large quantity of fatty matter, of a soft consistence, and which was at first regard-

ed as fat. But M. Chevreul, by a series of very ingenious experiments, has discovered that this matter is the same as that of the brain and nerves. Its chemical composition is very remarkable. It is an *azotic fat*, the reverse of all other bodies of this kind, which do not contain azote.

Messrs. Prevost and Dumas have demonstrated the presence of urea in the blood of animals deprived of their kidneys. M. Boudet, Jun., has found cholesterine, and some other elements of the bile, in the serum. Thus, as the analyses of the blood multiply, and the processes become more perfect, we find in the blood all the elements of the organs. We may now designate with confidence the fibrine as the same substance as the muscular fibre; the albumen, which forms so great a number of the membranes and tissues; the fatty matter that has been described, which, united with osmazome and albumen, form the nervous system; the phosphates of lime and magnesia, which constitute the greater part of the bones; the urea, one of the most remarkable excrementitial elements of the urine; the yellow matter of the bile, and which extends itself by imbibition into the cellular tissue about contusions, &c. When, by the aid of a strong magnifying-glass or microscope, we examine the transparent parts of cold-blooded animals, we discover in the sanguineous vessels an innumerable multitude of small, rounded particles, which swim in the serum, rolling one over the other as they pass from the arteries to the veins. These are the *globules*, or, more properly, the *discs of the blood;* they were discovered by Malpighi. Leewenhoek soon after engaged in examining them, probably without having given much attention to the vague communication of Malpighi on the subject. He described very precisely a great number of them. Since that time many persons have undertaken their examination; but there are only three that can be compared with Malpighi in the accuracy of their observations and their skill in the use of the microscope; these are Leewenhoek, Hewson, and Messrs. Prevost and Dumas. As they agree in the principal facts, and as the last have made use of the facts indicated by the others, we shall confine ourselves to their results.

They found globules in the blood of all animals. To ascertain this, a very small drop of blood may be placed upon a plate of glass, taking care to spread it lightly, without crushing it. Upon the edges there will always be found isolated globules or discs, that may be easily seen and measured.

With weak lenses they appear like black points; afterward they assume the appearance of white circles, in the midst of which is seen a black spot, when the magnifying power is increased. When magnified to three or four hundred times its diameter, the last presents the appearance of a bright spot. When the eye has become familiarized with this appearance, it preserves its powers of perception with weaker magnifiers. This is the key to most of the opinions that have been advanced upon this subject, and serves to reconcile them.

While the blood circulates in the vessels, the particles which it encloses have no other motion than that impressed upon them by the liquid. But it has been said that when removed from the vessels, they are vividly agitated, and that the little drop presents a peculiar tremour, which ceases in a few seconds. Sir Everard Home supposed that the blood contains globules, which are enclosed, in health, in a covering of colouring matter, of which they are the nucleus; and within thirty seconds after the blood has been taken from the vessels, that this exterior matter collects together, and forms a sort of collar about the central globule. Messrs. Prevost and Dumas differ from him essentially on this point, they regarding as the habitual state that which seemed to him as the effect of death. Their proofs appear to be irrefragable, as they repose on observing the circulation in the wing of a bat, the foot of a frog, the mesentery of certain fish, the tail of a tadpole, and the lung of a salamander.

They satisfied themselves, by numerous observations, that the appearances and diameter of the globules or discs were the same within and without the vessels. They saw that they were not endowed with a movement of rotation on their centre, as some writers had supposed, but that they followed simply the direction of the blood. It is easy to distinguish, in the foot of the frog and the tail of the tadpole, the different phases of the globules, and to satisfy ourselves of their flatness. Sometimes they are seen full; at others, more or less obliquely; again, their edge is presented to the observer. They balance themselves in the liquid in which they swim, and sometimes we see them turn slowly upon themselves, so that we can exactly appreciate their form.

Still farther, we can see them pass directly from the arteries into the veins, and the blood arrive on the one side and return on the other. There may be seen, at the same time, all the varieties of position which render so clear the true form of the globules of the blood. This disposition of the vessels enables us to conceive the alteration that has been sometimes remarked in the course of the blood, and the retrograde motion of the circulation during death, on which Spallanzani and Haller have so much insisted.

These different observations are sufficient to demonstrate that the globules of the blood are the same during life, and for some moments after they have issued from the blood-vessels, and that they are flattened in both instances. But they leave it still doubtful whether they possess elasticity, and whether they consist, as Hewson believed, and as Messrs. Prevost and Dumas thought they had proved, in a globule enclosed in a membranous sack.

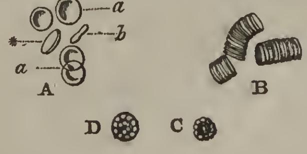
Since the publication of their memoir, the latter gentlemen have examined the lung of a salamander with a magnifier of three hundred diameters' magnifying power. The spectacle presented to them cannot easily be comprehended by the reader. The sanguineous particles moved with such velocity that at first caused a sensation of vertigo in the observer. But the circulation soon be-

came slower, and the particles could be seen to pass tranquilly along in the fluid in which they were contained; they crept slowly, as it were, in the small vascular ramifications, elongating themselves when the space was too narrow; or they stopped and remained for some time in the narrowest passages, until, pressed upon by those coming after them, they broke through the obstacle, and passed on. Sometimes they were suddenly stopped by the compact space which separated two of the vessels. It appeared as if a very flexible floating body had struck, at its centre of gravity, an obstacle which suddenly stopped its farther progress, the particle bending itself to the form of the opposing body. Still, as the current of the liquid continued to press on in the same direction, it would continue to oscillate for some time, uncertain whether to direct itself upon the vessel at the right or the left. Sometimes this state of things would continue for several minutes. It would probably have been still longer delayed, if the new particles coming in the same direction had not determined it one way or the other. These different movements left no doubt in their minds as to the form of the particles of the blood being membranous sacks, with a globule enclosed. Though, at the period of the publication of their memoir on this subject, their proofs of this were not decisive, yet they have not since found any reasons to doubt the conclusions at which they then arrived.

[On this point, however, it would seem there is still some reason to doubt. According to Dr. Carpenter, in man and most of the mammalia these particles or globules of the blood, as they have been usually called, are, in fact, discs with a circular outline. In man the sides of the disc are somewhat concave, the bright spot constituting the centre. This, which has been regarded as indicating the existence of a nucleus, Dr. Carpenter thinks, in reality, is attributable simply to the greater thinness of the disc at this point. The form of the disc appears to be altered by various re-agents. In water they assume a globular form. The following cuts, after Wagner, will illustrate these views.

(Fig. 37.)

Discs of the Blood, magnified about 500 diameters.

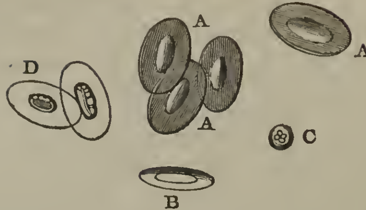


A. Single discs. *a a.* Their flattened globules. B. Globules seen edgeways. C D. Lymph globules.

With respect to the existence of a nucleus, Dr. Carpenter thinks it doubtful as regards the mammalia. But in the frog, the particles of which are much larger than in man, a nucleus may be observed to project.

(Fig. 38.)

Particles of Frog's Blood.



The red globules in the blood of the frog are larger than in man. A A. Their flattened face. B. Globule turned edgeways. D. Appearance when changed by dilute acetic acid. C. Lymph globule.

Thus, it appears, by taking fresh blood from an animal, and spreading it in thin laminæ, we may arrive at results as to its state during life. This is precisely the method of Messrs. Prevost and Dumas. They have described in their memoir their mode of measuring the diameters of the particles. The process presents some difficulties, undoubtedly; we may hope that a long use of the microscope has enabled them to execute it with some precision. In the works of Haller may be found his attempts to do this, as of others who had preceded him.

The following are some of the results:

Jurin	$\frac{1}{3240}$	part of an English inch.
According to experiments revised and approved by Leewenhoek	$\frac{1}{1940}$	" "
Young	$\frac{1}{1660}$	" "
Wollaston	$\frac{1}{5000}$	" "
Bawer	$\frac{1}{1700}$	" "
Kater	$\frac{1}{4000}$	" "

The last-mentioned number very nearly agrees with the observations of Messrs. Prevost and Dumas in twenty examinations of sound, and nearly the same number of diseased persons. They could trace no difference connected with age, sex, or disease. It is probable, however, that some difference exists, and the late researches of M. Bawer may lead to the discovery. With respect to inequalities in the particles in the same blood, this is very doubtful. Nothing can be more regular than that of the particles in the human blood. It is very rare that particles are observed different from the rest in their diameter. Messrs. Prevost and Dumas always found, where this appeared to be the case, it was a mere optical illusion.

It appears, then, that the method adopted by Messrs. Prevost and Dumas presents results comparatively, if not absolutely, accurate. They are all that the present necessities of the science claim. They show that the particles of the blood are circular in the mammiferi, and elliptical in birds and cold-blooded animals;

and that they are flat in all animals, and composed, at least in some, of a nucleus enclosed in a membranous sack.]

Apparatus of the Arterial Blood.

It is composed, first, of the pulmonary veins ; second, of the left cavities of the heart ; third, of the arteries.

Pulmonary Veins.

They arise, like the other veins, in the tissue of the lungs ; that is, they consist at first of an infinite number of radicles, which are continuations of the pulmonary artery ; these branches, uniting, form small trunks, which gradually become larger. At last all these trunks terminate in four vessels, which, after running a short distance, open into the left auricle of the heart. The pulmonary veins differ from all other veins in this, that they do not anastomose with each other when they have acquired a certain size. We have observed a similar disposition in the divisions of the artery which is distributed to the lungs. The pulmonary veins have no valves, but their structure in other respects is similar to the other veins ; their middle membrane is, however, a little thicker, and seems to possess a greater degree of elasticity.

Left Cavities of the Heart.

The form and size of the left auricle differ but little from the right ; its surface only is smoother, and does not present any fleshy column (except in the appendix called *oricule*). It communicates by an oval opening with the left ventricle, which is distinguished from the right by the greater degree of thickness of its walls, and the number, volume, and disposition of its fleshy columns. The opening by which the auricle and ventricle communicate is garnished by what is called the mitral valve, which is very analogous to the tricuspid. The ventricle gives origin to the artery called the aorta, the orifice of which presents three semi-lunar valves very similar to the pulmonary artery.

Of the Arteries.

The aorta is to the left ventricle what the pulmonary artery is to the right, though it differs in many important particulars. Its capacity and extent are much greater ; nearly all its divisions are considered as arteries, and have each received particular names. Its branches anastomose with each other in various modes ; they often present numerous and remarkable flexuosities. They are distributed to every part of the body, and effect in each a peculiar arrangement ; they communicate with the veins and lymphatic vessels. In other respects the structure of the aorta strongly resembles the pulmonary artery ; its middle membrane is, however, much thicker, and more elastic. Through nearly its whole extent the aorta is accompanied by filaments, arising from the ganglions of the great sympathetic nerve. These filaments appear to be distributed to its walls.

Course of the Arterial Blood in the Pulmonary Veins.

In treating of the course of the blood in the pulmonary artery, we pointed out how this fluid arrived at the extreme branches of this vessel. The blood does not stop there; it passes into the extreme branches of the pulmonary vein, and soon into the trunks of this vein; in its passage, its motion is gradually accelerated as it passes from the small into the large veins. It does not run with a jerk, and is nearly of equal rapidity in the four pulmonary veins. But let us inquire, What cause determines the progress of the blood in these veins? We naturally refer this to the contraction of the right ventricle, and the elasticity of the walls of the pulmonary artery. Indeed, having forced the blood to the extreme ramifications of the pulmonary artery, we cannot conceive why these two causes should not continue its motion even in the pulmonary veins.

This was the opinion of Harvey, who first demonstrated the true course of the blood; but modern physiologists have found this explanation too simple. It is now generally admitted that, when the blood has arrived at the extreme ramifications of the pulmonary artery, and entered the radicles of the pulmonary veins, or, as they are commonly called, *capillary vessels of the lungs*, it no longer moves from the influence of the heart, but by an action peculiar to the small vessels that it traverses. This idea of the action of the capillary vessels is extremely convenient in physiology; after the vital properties, there is nothing which more facilitates our explanation of the most obscure phenomena. Let us, therefore, examine it with attention; and first, has this action ot the capillaries been witnessed by any observer? Does it fall within the scope of our senses? No; no one pretends to have seen it; it is only a thing supposed.* But let us admit for an instant the existence of this capillary action; in what does it consist? Is it a greater or less degree of contraction, by which the blood, with which they are filled, is forced forward? In contracting from their elasticity, they would undoubtedly propel the blood; but can any reason be assigned why they should direct it rather towards the veins than arteries? Finally, when the small vessels were once emptied, how would they be filled again? This could only be by the force of the heart propelling blood into them, or else from their dilating in such manner as to attract this fluid from the neighbouring vessels; according to this supposition, it would be as likely to attract the blood from the veins as from the arteries. If we admit, therefore, a position, which is merely gratuitous, that the capillary vessels dilate and contract themselves alternately, we still should not be able to explain the function attributed to them. That they may perform this function, it would be necessary that each capillary vessel should be arranged in a manner

* This action is directly contrary to observation. In the lungs of reptiles we may see the blood pass from the arteries into the veins with a common magnifying glass, but no action of these vessels. But the slightest change of dimension is very apparent; it is the same in certain warm-blooded animals, where the blood can be seen traversing the capillaries.

analogous to the heart; that it should be composed of two parts, in which one dilated, while the other contracted itself, and that there should be between them a valve analogous to the mitral valve. Yet, even with this complicated apparatus, the course of the blood in these vessels would not be uniform.

In whatever point of view, therefore, we examine this action of the capillary vessels, it is found vague and contradictory. In reptiles, in which, by the aid of a microscope, it is easy to distinguish the blood of the pulmonary artery passing into the veins, no motion can be perceived at the point where the artery terminates in the veins; the motion of the blood is nevertheless manifest, and even rapid. We must conclude, then, that the capillary action of the vessels of the lungs giving motion to the blood in the pulmonary veins is a mere supposition, an effort of the imagination; in a word, purely hypothetical; and that the true cause of the passage of the blood into the pulmonary artery and veins is the contraction of the right ventricle of the heart.

I am far from thinking that the small vessels at all times equally favour the passage of the blood; we have a proof to the contrary at each inspiration and expiration. When the lungs are distended with air, its passage is easy; but when the chest is contracted, the lungs containing but little air, it becomes more difficult. It is, besides, extremely probable that they dilate themselves, according to the quantity of blood which traverses the lungs, and many other circumstances. I am ready to believe that, according as they are distended or contracted, they may influence the progress of the fluid that traverses them; but I cannot admit that they are capable of modifying the course of the blood, or that they are the sole agents of its motion.

The eighth pair of nerves appears to have a great influence upon the passage of the blood through the lungs. It is very probable that it modifies the disposition of the capillary vessels of these organs; when we inject water into the pulmonary artery, in the dead body, it passes immediately into the veins; a part of it, however, escapes into the cells of the bronchiæ, where it mixes with the air, and forms froth; another portion escapes, and becomes infiltrated into the cellular tissue of the lungs. After a certain time, when this infiltration has become somewhat considerable, it then becomes impossible to force the injection farther into the pulmonary veins. Similar phenomena occur when, instead of water, blood is injected into the pulmonary artery. These phenomena, as we have seen, have a great analogy with those produced by the section of the eighth pair of nerves in living animals.

When we recollect the extremely small calibre of the capillaries of the lungs, we can comprehend the remarkable tenuity of volume of the globules of the blood, and their utility. If the solid and insoluble part of the blood had not been divided into these very minute masses, it could not have traversed the minute vessels by which the arteries are united to the veins. Experiment proves this; I injected into the veins of an animal an impalpable

powder of charcoal and sulphur, suspended in a little gum-water. The animals died almost immediately; on opening their bodies, I found the pulmonary capillaries completely choked up by the injected powder, which was too gross to pass them.

If the blood be very viscid, and its particles separate with great difficulty, the circulation will soon stop, because the blood cannot traverse the lung, and it becomes engorged. Many grave maladies, no doubt, owe their origin to this cause. We may cause almost immediate death in animals by introducing viscid substances into the circulation, such as oil, mucilage, metallic mercury, &c., as was observed by M. Gosford (*Journ. de Physiol.*, t. i.).

In diseases attended with alteration of the pulmonary tissue, as pneumonitis, gray hepatization, &c., I have satisfied myself that the passage of an aqueous injection from the pulmonary artery to the veins is extremely difficult, or even impracticable. In certain cases, where there existed before death an abundant expectoration, the injection passed into the bronchiæ. In a word, I have strong reasons to suspect that most organic lesions of the lungs consist in an obstruction, to a greater or less extent, of the blood through the pulmonary capillaries; consequently, of an extravasation of the different elements of the blood into the parenchyma of the lungs.

Absorption of the Pulmonary Veins.

Like the other veins, the pulmonary veins absorb, and carry to the heart, those substances which are in contact with the spongy tissue of the air-cells of the lungs. It is sufficient to inspire once air charged with odoriferous particles, in order that it may become manifest in the animal economy. The deleterious gases, medicinal substances spread through the air, contagious miasmata, certain poisons or medicines applied to the tongue, produce effects which astonish us by their promptitude. The mode by which the absorption is effected, which was long unknown, and the object of numerous speculations, is extremely simple. It depends on the physical properties of the vascular walls. If a gas or vapour penetrate into the lung, these substances traverse the membranes which form the walls of the small vessels, and mingle with the blood. If it be a liquid, it is imbibed by the same walls, and enters the cavity of the vessels. It soon becomes mingled with the blood, and as the walls are very thin, the passage, or, what is the same thing, the absorption, is very rapid.

In epidemic and contagious diseases, it is most desirable to seek for remedies which, in the form of vapour, gas, &c., may be introduced with the air into the lungs. The attendants upon persons labouring under dangerous diseases, where the emanations are fetid, should take great precautions, by ventilation and cleanliness, to avoid breathing them.

Passage of the Arterial Blood through the Left Cavities of the Heart.

The mechanism by which the blood traverses the left auricle and ventricle is the same as that by which the venous blood traverses the right cavities of the heart. When the left auricle dilates, the blood is poured in by the four pulmonary veins, and fills it. When, afterward, it contracts itself, one part of the blood passes into the ventricle, another flows back into the pulmonary veins. When the ventricle dilates, it receives blood from the auricle, and a small portion from the aorta. When it contracts itself, the mitral valve is raised, and closes the opening between the auricle and ventricle, so that the blood cannot return into the auricle; it is, therefore, forced into the aorta, pushing before it the three semilunar valves with which the vessel had been closed during the dilatation of the ventricle.

It is proper, however, to remark that, as there are no fleshy columns existing in the left auricle, it cannot be supposed to have the same influence upon the blood that we have supposed to be exerted by the right; and, as the left ventricle has much thicker walls than the right, it must compress the blood with much greater force, which is indispensable, from the great distance this fluid has to pass over.

Course of the Blood in the Aorta, and its Divisions.

Notwithstanding the differences which exist between this and the pulmonary artery, the phenomena of the course of the blood are nearly the same. Thus, a ligature being applied upon this vessel near the heart in a living animal, it becomes contracted through its whole extent, and the blood, with the exception of a certain quantity which remains in the principal arteries, passes in a few moments into the veins.

Some authors have called in question the fact of the contraction of the arteries under these circumstances. We may demonstrate this by the following experiment: Lay bare the carotid artery in a living animal for several inches in extent; tie it at two different points; take with a compass the transverse dimensions of the vessel, and you will then have a portion of the artery full of blood; make into the walls of this portion of the artery a small opening, and you will immediately see the blood almost entirely pass out, darting even to some distance. Measure, afterward, the size with a compass, and you will not then doubt that the artery is very much contracted, if the prompt expulsion of the blood has not already convinced you. The experiment proves also, contrary to the opinion of Bichat, that the force with which the arteries react upon themselves is sufficient to expel the blood they contain. I will immediately give other proofs of this. During life, this total expulsion cannot take place, because the left ventricle throws out, at every moment, new masses of blood into the aorta, and this blood replaces that which is continually passing into the veins.

Every time that the ventricle forces blood into the aorta, it is distended, as well as all its ramifications of a certain calibre. But this dilatation becomes less as the arteries become smaller, and it ceases altogether in those which are very small. These phenomena are, as we see, the same already described in speaking of the pulmonary artery. The explanations that we then gave may with propriety be applied here.

The polished surface of the interior of the arteries must be very favourable to the motion of the blood; we know, at least, that it diminishes when this is removed by certain diseases; the course of the fluid becomes slower, and sometimes ceases altogether. This is probably also the reason why blood will not pass long through a tube introduced into the extremity of an open artery. It is very probable that the friction of the blood against the walls of the arteries, its adhesion to these walls, its viscid nature, &c., must have great influence upon its motion. But it is impossible justly to appreciate these different causes, either combined or separate. Independently of these phenomena common to all the arteries, there are some which are peculiar to the aorta, and which depend upon the anastomoses existing between its branches, and the innumerable curvatures which are found in the greater number of them.

Whenever an artery presents a curvature, there is, every time the ventricle contracts, a tendency in it to assume a straight line; this tendency manifests itself by an apparent motion, called by some authors locomotion of the artery, and which may be considered as a principal cause of the pulse. This motion is most remarkable when it is observed near the heart, and in one of the large arteries. In the arch of the aorta it is most apparent. It may be easily explained. One consequence to be deduced from this fact is, that it is mechanically impossible that the windings of the artery, particularly when they are sudden, should not retard the course of the blood. Bichat is entirely mistaken in this respect, when he asserts, that the meanderings of the artery have no influence. This could not happen, he says, unless the arteries were empty when the heart sent forward its blood to them; but, as they are constantly filled, this effect cannot take place. Now, inasmuch as each curve of the artery has such a force expended upon it as to give the vessel a tendency to become straight, there will be, necessarily, so much less force for the motion of the fluid; and, of consequence, its motion will be retarded by these curvatures.

It is much more difficult to explain the influence of the different anastomoses. Their utility is very evident; through them the arteries mutually supply each other, and distribute blood to the organs; but we are unable to say, with accuracy, what influence they exert upon the progress of the blood. If the dimensions, curves, and anastomoses of the arteries essentially modify the course of the blood, it is impossible that all the organs in which each of these circumstances exist in different degrees should receive the blood with the same degree of rapidity, and, of conse-

quence, with the same force. The brain, for example, receives four large arteries for itself alone; but these arteries run in a very tortuous direction, with many sudden turns, before they penetrate the cranium; when they have arrived there, they anastomose very frequently; and, finally, they do not enter into the tissue of the organ until they have become extremely small. The blood must therefore circulate but very slowly in this organ. The kidney, on the contrary, has but one artery, which is short and voluminous, which at once buries itself in its parenchyma, and is divided into large branches; the blood must, therefore, pass through it with great rapidity.

Thus, by all the concurrent circumstances which modify the course of the arterial blood, it becomes resolved into a very complicated hydraulic problem, viz., the continued distribution of a fluid, varying essentially in quantity and rapidity in different parts, through a single system of tubes, of unequal capacity, by means of a single agent of alternate impulsion.

In the number of phenomena exhibited in the course of the arterial blood, we have placed the dilatation and contraction of the arteries. Bichat does not admit the existence of these phenomena. This author will not allow that the arteries dilate at the instant when the ventricle contracts; and he formally denies that they contract to force the blood into the different parts. I think, however, that, with a little attention, it is possible to see distinctly these two phenomena when the artery is laid bare. They are, for example, evident in the large arteries, such as the thoracic and abdominal aorta, especially in large animals; but to render them apparent upon smaller arteries, we may make the following experiment: lay bare the crural artery and vein of a dog to a certain extent; then pass behind these two vessels a ligature, which must be drawn very tight over the posterior part of the thigh. The arterial blood will thus be prevented from arriving at the limb, except through the crural artery, and can only return through the crural vein. Measure with a compass the diameter of the artery, afterward press it between the finger and thumb, so as to intercept the blood, and you will see, in a short time, that part of the artery which is beyond the fingers become emptied of the blood which it contained. Allow the blood afterward to penetrate into the artery, by removing the compression; you will then see it again become distended with blood at each contraction of the ventricle, and resume its former dimensions.

But though I consider the contraction and dilatation of the arteries as a point completely ascertained, I am far from thinking, with some authors of the last century, that they dilate themselves, or that they are contracted by muscular fibres. I think, on the contrary, that they are passive in both cases; that is, that their dilatation and contraction are simply the effects of the elasticity of their walls acted upon by the blood, which is continually forced into their cavity by the contraction of the ventricles of the heart.

There is a difference in this respect between the large and small arteries; I have proved, by direct experiments, that the arteries do not exhibit any evidences of irritability; that is, they remain immovable under the application of pointed instruments, caustics, and a stream of the galvanic fluid. Not being able to detect the contractility of the walls of the arteries, Bichat thought it necessary to deny the important phenomenon which he supposed to be the effect of it. He did not believe that the blood ran on in a continued stream in these vessels; but he supposed that the entire mass of fluid was displaced at the instant that the ventricle contracted, and was immovable when it was in a state of relaxation, as would happen if the walls of the arteries were inflexible. This opinion has been supported very recently by Dr. Johnson, an English physician. He has even constructed a machine which, according to him, renders this thing evident. But it is sufficient to open the artery in a living animal to see that the blood will pass out in a continued stream; with a jerk if the artery be large, and uniformly if it be small. Now the action of the heart being intermitting, it is impossible that it should produce a continued stream. The arteries must, therefore, act upon the blood.

The elasticity of the arterial walls has the effect of a reservoir of air in certain pumps, which act alternately, and which, therefore, furnish the fluid in a continued stream. We know, in general, in mechanics, that every intermitting motion may be changed into a continued one by employing the force that produces it to compress the receiver, which reacts in a continued manner.

Passage of the Arterial Blood into the Veins.

When an injection is forced into an artery in the dead body, it returns promptly by the corresponding vein. The same thing takes place, and with still greater facility, if the injection be made into the artery of a living animal. In cold-blooded animals, by the aid of a microscope, we can distinguish the blood passing from the arteries into the veins;* the communications between these two kinds of vessels is, then, direct, and extremely easy. It is natural to suppose that when the heart has forced the blood into the extreme arteries, that it continues to give it motion after it has reached the branches, and even the trunks of the veins. Harvey and a great number of distinguished anatomists have thought the same. Bichat has opposed, with great force, this doctrine, and has endeavoured to fix limits to the influence of the heart. He supposes that this action ceases at the point where the arteries terminate in the veins. According to him, the action of these small vessels alone is the cause of the motion of the blood.

We have already combated this supposition, in speaking of the course of the blood in the lungs; the same reasoning applies perfectly here. Bichat asserts that this capillary action consists in a

* Cowper asserts that he witnessed the same phenomenon in warm-blooded animals: I have repeated his experiments without success.

"*kind of oscillation or insensible vibration of the walls of these vessels.*" Now I ask how *an oscillation or insensible vibration of the walls* can determine the motion of a fluid contained in a canal? Again, if this vibration be *insensible*, who can undertake to decide upon its existence? Let us not, therefore, render complicated a simple question, by a supposition vague and destitute of proof; but let us admit an explanation which presents itself naturally to the mind, viz., that the contraction of the heart is the principal cause of the motion of the blood, both in the arteries and veins.

The following experiments appear to me to render this phenomenon very evident. After having passed a ligature about the thigh of a dog, in the mode just pointed out, that is, without including either the crural artery or vein, apply a ligature separately upon the vein near the groin, and make a slight puncture in the vessel; the blood will then escape, forming a jet. Then press the artery between the finger and thumb so as to prevent the arterial blood from passing to the limb; the jet of venous blood will not stop instantly, but it will continue for a few moments. At last, however, the column will diminish, and finally stop, though the vein may be full through its whole extent. If, during the production of these phenomena, we examine the artery, we shall see that it becomes gradually contracted, and at last completely empty. At this period of the experiment, let the compression upon the artery be removed, and the blood, being propelled by the heart, will soon arrive at the extreme ramifications of the artery; the column of blood will now be soon seen to pass out from the opening in the vein, and by degrees the jet will become perfectly established as before. Compress anew the artery until it becomes empty; afterward, allow the blood to penetrate slowly. Under these circumstances, the blood will continue to pass out in a small stream from the vein, but not in a jet, which will, however, take place when the artery is left entirely free. Analogous results may be obtained by forcing an injection of warm water into the artery instead of allowing the blood to penetrate it; the more force used in pushing forward the injection, the more promptly will the fluid pass out from the vein.

I observed, in speaking of the lymphatic vessels, that they communicate with the arteries, and that injections pass readily from one into the other. This communication becomes still more evident when we inject saline or coloured fluids into the veins in a living animal. I have satisfied myself often that these substances pass into the lymphatic vessels in the course of two or three minutes, and that their presence may easily be demonstrated in the lymph extracted from these vessels.

As long as the veins which pass out from the organs are free, the blood which arrives by the arteries traverses their parenchyma, and is not accumulated. But if the veins are compressed, or are unable to empty themselves of the blood which they contain, this fluid, still continuing to arrive by the arteries, and finding no opportunity to escape into the veins, becomes accumulated in the

tissue of the organ, distends the sanguineous vessels, and augments more or less its volume, especially if its physical qualities be such as to favour these changes. This phenomenon may be observed in many organs; but, as it is most apparent in the brain, it has been most frequently remarked there. This swelling of the brain from an obstruction in the circulation happens whenever the course of the blood through the lungs is interrupted; and as this takes place generally during expiration, the brain at this moment becomes swollen in proportion as the expiration is longer and more complete. In young animals, where the brain receives proportionally more arterial blood, the swelling is much more remarkable.

Remarks on the Motions of the Heart.

The right auricle and ventricle, and the left auricle and ventricle, the actions of which we have investigated separately, really form but one organ, *the heart.* The auricles contract and dilate at the same moment; the motion of the ventricles is also simultaneous. When we speak of the contraction of the heart, it is to the ventricles that we particularly refer. Their contraction is called the *systole,* and their dilatation, the *diastole* of the heart.

The contraction of the auricles is generally abrupt and rapid, and is often twice to one contraction of the ventricles. Their dilatation is slower, because it depends upon the blood of the venæ cavæ and pulmonary veins; if these veins be full, it distends them promptly. The sanguineous columns are sometimes poured so rapidly into the auricles, that their walls do not contract, except as far as depends upon their elasticity. I have frequently observed this phenomenon in the inferior animals, and have no doubt that it also often happens in man. Here, as in many other instances, elasticity advantageously supplies the place of muscular contractility.

Every time that the ventricles contract, the whole of the heart is thrown suddenly forward, and the apex of this organ strikes against the walls of the left side of the chest, near the space between the sixth and seventh true ribs. This is accompanied with a particular sound, of which we shall soon speak. This displacement anteriorly of the heart during its systole has given occasion to a long and spirited controversy. Some contend that the heart becomes shortened during its contraction; others maintain that it becomes elongated, and that this is necessarily the case; otherwise it could not strike against the walls of the thorax, inasmuch as it is more than an inch distant from it during its diastole. A great number of animals were uselessly sacrificed in examining this motion of the heart; at the same moment some asserted that they saw the heart shortened, while others as strongly affirmed the reverse. What experiments could not determine, a very simple reasoning makes clear. Bossuet interfered in the controversy, and showed that, if the heart were elongated in its systole, the mitral and tricuspid valves, being retained by the

fleshy columns, could not close the openings between the ventricles and auricles. The partisans of the lengthening of the heart persisted no farther; but it remained to be shown how the ventricle could be shortened as the heart was carried forward. Senac proved that this depended upon three causes. First, the dilatation of the auricle, which takes place during the contraction of the ventricle; second, the dilatation of the aorta and pulmonary artery, in consequence of the blood introduced into them by the ventricles; third, the tendency in the arch of the aorta to be thrown into a straight line by the contraction of the left ventricle.

The contraction of the ventricles and the motion of the heart against the left wall of the thorax are accompanied with a dull, but distinct sound, when the ear is applied to the cardiac region. This sound is preceded by another sound, that has been noticed in speaking of the right ventricle, which accompanies the dilatation of that cavity. These two sounds, which succeed each other rapidly, constitute what are called in pathology *the sounds of the heart*, and are important in the organic and other affections of this organ. Both result from the shock or impulsion of the heart against the walls of the chest. The first, or the dull sound, depends, as I have said, on the impulsion of the apex of the heart on the interspace between the sixth and seventh rib. It may be produced at other points, if by any cause the heart is displaced, or the parietes of the thorax deformed. The dull character of the sound appears to depend on the mass of the striking body, and the little elasticity of the body struck.

The second sound corresponds to the dilatation of the ventricles, and the consequent rapid entrance of the blood into its cavities. The production of this sound has been attributed to the contraction of the auricles; and also to the blood being suddenly introduced within the ventricles, and striking against the walls, so as to excite sonorous vibrations. But neither of these explanations is well founded. I have already stated, that when the heart is exposed, at the moment it acts with the greatest energy, no sound is produced unless it strikes against some of the neighbouring parts. If we introduce through the thoracic walls of a dog, as I have repeatedly done, a small movable stem over the right ventricle, and another over the apex of the heart, it will be easy to see that each of these sounds is accompanied by a shock, which manifests itself clearly on the outside by an extensive movement of these small stems. If the second sound be clearer, it is no doubt attributable to the inconsiderable mass of the striking body, and to the part struck, *the sternum*, which is much more sonorous than the lateral wall of the thorax, which is chiefly muscular.

The number of pulsations of the heart is considerable, and is greatest in the early periods of life.

At birth it is from	130	to 140	in a minute.
At one year,	120	130	"
At two years,	100	110	"
At three years,	90	100	"

At seven years it is from	85 to	90	in a minute.
At fourteen years,	80	95	"
At the adult age,	75	80	"
In old age,	65	75	"
Extreme old age,	60	65	"

But these numbers vary according to an infinite number of circumstances, such as sex, temperament, individual disposition, &c. The affections of the mind have a great influence upon the rapidity of the contractions of the heart; every one knows that an emotion, however slight, modifies these contractions, and often accelerates them. Diseases produce great changes in this respect.

Many researches have been made to ascertain the force with which the ventricles contract. To appreciate that of the left ventricle, an experiment has been made, which consists in crossing the legs, placing the ham of one leg upon the knee of the other, and suspending at the end of the foot a weight of fifty-five pounds. This considerable weight, though placed at the extremity of so long a lever, is raised at every contraction of the ventricle, in consequence of the tendency to become straight, which occurs in this accidental curve of the popliteal artery, when the legs are crossed in this manner. This experiment shows that the contractile force of the heart is very great, though it does not enable us to form any accurate estimate of it. The mechanical physiologists made great efforts to express it in numbers; Borelli compared the force with which the circulation is carried on to a power that would be necessary to raise a weight of 180,000 pounds; Halles supposed it to be 51 pounds 5 ounces; and Keil reduced it to five or eight ounces. Which shall we consider the truth among such palpable contradictions?

M. Poiseuille has invented an ingenious instrument with which he proposes to measure the force of the heart, avoiding the obstacles which opposed the means of appreciation employed by his predecessors. This instrument consists of a curved tube, the vertical part of which is graduated with a metrical scale, and filled with mercury; the horizontal part, which is to be adapted to the arteries and veins, is filled with a solution of the sub-carbonate of soda, which prevents the blood from coagulating. He has called this instrument the HEMO-DYNAMOMETER.

With this instrument M. Poiseuille has arrived at results which, though not such as might have been desired as relates to determining the force of the heart, are at least very remarkable as respects the mechanical phenomena of the circulation. I will cite the following fact, that it would have been difficult to foresee in the actual state of science.

If the instrument be fitted to a large or a small artery near to or remote from the heart, the height of the mercurial column is the same. Thus, when applied to the carotid of a horse, the point of elevation of the mercury is the same as when applied to a small dog. From the identity of these results, the author concludes *that a molecule of the blood is moved with the same force*

through the whole course of the arterial system ; a conclusion which appears to us to go beyond what the experiments prove. To generalize, as this author has done, would require certain experimental data, not in those vessels which are large enough to have this instrument adapted to them, but the more minute vessels, even the capillaries, if possible.

M. Poiseuille afterward establishes the following general theorem: *The total static force which moves the blood in an artery is exactly in direct proportion to the area which the circle of that artery presents, or in direct proportion of the square of its diameter, wherever it may be situated.*

It appears to be impossible to determine precisely the force developed by the heart during its contraction. It is obvious that it must vary with a multitude of causes, such as the age and size of the individual, the quantity of blood, state of the nervous system, the action of the organs, health and disease, &c.

All that has been said respecting the force of the heart applies to its contraction. Its dilatation has been regarded as an active phenomenon, and I have myself entertained that opinion. But it does not appear to me to be so at present. In again carefully studying the dilatation of the heart, it has seemed to me that its contraction compresses the fibres of the organ, that their elasticity is developed under this influence, and that immediately, as soon as the contraction ceases, the fibres return to their natural length with the more energy in proportion as they have been compressed. There is developed, as we have seen, a phenomenon of this kind immediately after the contraction of a bundle of muscular fibres, the effect of the galvanic current. To this physical cause of the dilatation of the cavities of the heart we must add the force of the column of blood which is introduced into them by the auricles, and which is undoubtedly a powerful influence in separating their walls. It must be kept in mind that the auricles contract with considerable force, pouring the blood into the cavities of the ventricles. The contraction of the right ventricle, then, through the medium of the pulmonary artery and veins, is one of the causes of the dilatation of the left ventricle. The contraction of the left ventricle acts in the same way in the dilatation of the right auricle, through the medium of the blood that fills the arteries and veins; lastly, the contraction of each auricle contributes to enlarge the ventricle to which it is attached.

From the first moment of the existence of the embryo until death takes place from decrepitude, the heart continues to beat. What is the cause of this? This question has often been proposed, both by ancient and modern philosophers and physiologists. The causes of phenomena are not easily assigned in physiology. It almost always happens that what are considered such are nothing more than descriptions of these phenomena in different terms. But it is curious to remark the facility with which we suffer ourselves to be abused in this respect; the different explanations of the motion of the heart are most palpable proofs of this. The

ancients asserted that there was in the heart a peculiar virtue, a concentrated fire, which gave motion to this organ. Des Cartes imagined that there took place in the ventricles a sudden explosion, like that from gunpowder. The motion of the heart was afterward attributed to the animal spirits, the nervous fluid, the *præses systematis nervosi*, and the *archeus;* Haller considered it as an effect of irritability. Recently M. Legallois has endeavoured to prove, by experiments, that the principal cause of the motion of the heart had its seat in the spinal marrow.

These experiments of M. Legallois consisted in destroying successively, in living animals, the spinal marrow, by introducing a metallic staff into the vertebral canal. The result is, that the force with which the left verticle contracts diminishes in proportion to the destruction of the spinal marrow, and when it is complete, the heart no longer possesses power of propelling the blood to the extremities. From these experiments, which have been multiplied and varied with great ingenuity, M. Legallois concludes that the cause of the motion of the heart exists in the spinal marrow. As it has been remarked that this organ continues to contract for a considerable time after the complete destruction of the spinal marrow, and that its motions continue regular even after it has been separated from the body, M. Legallois explains these facts by saying that these motions are not the true contractions of the heart; that they are only the simple effects of the irritability of the organ.

To make good this explanation of M. Legallois, it would be necessary to show, by experiments, in what the difference between the irritability of muscular fibres and their power of contraction consists. This important distinction not having yet been established, I conceive that we cannot conclude from the labours of M. Legallois anything more than that the spinal marrow has an influence upon the force with which the heart contracts; but we can by no means infer that it is the cause of the motions of the heart.

The organs which transmit to the heart the influence of the brain and spinal marrow are nervous filaments coming from the eighth pair, and perhaps a great number of filaments of the cervical ganglions of the great sympathetic. M. Dupuytren and myself have endeavoured, for several years, to determine, by the extraction of the cervical ganglions, and even the first of the thorax, the influence of the ganglions upon the motion of the heart; but our efforts have been thus far unsatisfactory. The animals have nearly all died in consequence of the wound unavoidable in extracting them. We have never remarked any direct influence upon the heart.

Remarks on the Circulation of the Blood.

We are now acquainted with all the links that form the chain which the sanguineous system represents. We know how the blood is carried to the lungs, and to every part of the body, and

how it returns again to the heart. Let us now examine these phenomena in a general manner, that we may impress the most important of them more strongly upon our minds.

The quantity of blood contained in the sanguineous system is very considerable. It has been estimated, by many authors, at from twenty-four to thirty pounds. This estimate cannot be very exact, as the quantity must vary according to a variety of causes. Youth and infancy have a larger proportion of blood than advanced age. It is more than probable that full-grown individuals, whose bodies are well developed and life active, have more blood than debilitated and emaciated persons. Plethoric persons, also, who are subject to hemorrhages from the nose and hemorrhoidal veins, must have a larger quantity of blood than those who are not thus constituted. Experiments made by me upon dogs have given results analogous to these conjectures as respects man. A dog of middle size does not furnish, by rapidly bleeding to death, but about a pound if emaciated and weak; if vigorous and in good condition, it may furnish double that quantity. We know but little better the difference between the mass of arterial and venous blood. The last, being contained in vessels the capacity of which is superior to the arteries, must necessarily contain the most, though we cannot say exactly how much it exceeds.

The size of the body bears a certain relation to the quantity of the circulating fluid. Persons of great stature have an enormous quantity of blood, as we may see by the copious and repeated bleedings they are capable of enduring, and from the state of the blood-vessels after death. In some individuals the aorta and its divisions, and the venous system, are two, or even three times more capacious than the same organs in others of the same height, but less corpulent.

In living animals the dimensions of several of the organs may be increased at pleasure. Take, for example, the spleen of a dog; after the abdomen has been opened, transfuse a pint of the blood of another dog into its veins. On doing so, you will see the spleen gradually enlarge, until, by the time that the injection is completed, it will become a third, or even a half larger than at first. Or, perform the opposite experiment; after measuring the size of the spleen in an animal, bleed it until it faints. On doing so, you will see the spleen diminish sensibly in volume in proportion as the blood is poured out. Similar observations may be made on the liver, but the tissue of that organ being less extensible than that of the spleen, the changes in volume are less remarkable.

It is easy to satisfy one's self that the length of the intestinal canal and the thickness of its walls are also in proportion to the circulating mass. In strong, vigorous, and plethoric individuals, in whom the abdomen is much developed, the walls of the intestines are very thick, the cavity large, and the length of the canal more than twelve yards. In thin persons, whose abdomen is flat instead of prominent, and who have little blood, the parietes of

the tube are thin, the cavity narrow, and the whole length often does not exceed five yards. We may easily make analogous observations upon the skin.

What has been said of the dimensions of the spleen, as relates to the volume of blood, may throw some light upon the functions of this singular organ. From what we have said, the spleen is a true reservoir, with elastic walls, which press constantly on the contained blood, and which tends to make it pass into the system of the vena portæ. The thinness and want of elasticity in the walls of that vein, and the absence of valves, readily allow the blood pressed by the spleen to penetrate there. The spleen also may more readily expel the blood contained in it, not only from its elasticity, but from its possessing a peculiar contractile power, which is quite apparent under the influence of certain drugs, particularly the nux vomica.

The circle through which the blood passes being uninterrupted, and the capacity of the canal being very variable, the rapidity of this fluid must be very different; because the same quantity must pass through every part in a given time, which is confirmed by observation. The rapidity is greatest in the trunk and principal branches of the aorta and pulmonary artery; it diminishes much in the secondary branches, and still more at the point where the arteries terminate in the veins. It afterward augments, as the blood passes from the extreme vessels into the larger trunks of the veins, but its rapidity is never as great in the venæ cavæ as in the aorta.

In the trunks and principal divisions of the arteries, the motion of the blood is continued, not only by the influence of the elastic power of the arteries, but it is also thrown out in a jerk by the contraction of the ventricles; this jerk manifests itself in the arteries by a simple dilatation in those which are straight, and by a dilatation and an effort to become straightened in those which are flexuous. The first phenomenon with which this second circumstance is connected is the pulse. It is not easy to study this in man or animals, except at those places where the arteries run upon the bones, because there they do not move from the finger applied over them, as is the case with those which float in the midst of soft parts.

The pulse frequently makes us acquainted with the principal modifications of the contraction of the left ventricle, its promptitude, intensity, weakness, and regularity or irregularity. We know also by the pulse the quantity of the blood; if it be great, the artery is rounded, large, and resisting; if little, the artery is small, and easily compressed. Certain states of the arteries influence the pulse, and may render it different in the principal arteries.

The pulsations of the arteries are necessarily perceptible in the neighbouring organs, in proportion as the arteries are large, and the organs yield easily. The agitation they experience is considered favourable to their action, though there is no positive proof

of this. In this respect no organ is influenced more than the brain. The four cerebral arteries, uniting in circles at the base of the cranium, elevate the brain at each contraction of the ventricle, as may be easily seen by laying bare the brain of an animal, or by observing this organ in wounds of the head. It is probably to moderate this agitation that the numerous curves of the internal carotid and vertebral arteries are made, before their entrance into the cranium. These flexuosities must necessarily retard the course of the blood through these vessels. When the arteries penetrate into the parenchyma of organs in large trunks, as the liver, kidney, &c., the organ must undergo great agitation at each contraction of the heart. The organs where the vessels do not penetrate until they have become divided and subdivided, do not experience this.

All the blood that passes from the lungs to the left auricle of the heart is of the same nature; it, however, sometimes happens that it is not precisely similar in the four pulmonary veins.* If, for example, a portion of the lungs be altered to such an extent that the air cannot penetrate into its air-cells, the blood that traverses it will not be changed from venous to arterial blood; but it will arrive at the heart without having undergone this transformation. In its passage, however, through the left cavities, it will be intimately mixed with the rest of the blood. The blood which goes from the left ventricle must necessarily be homogeneous, until it reaches the farthest branches of the aorta; but when it arrives at the smallest vessels, its elements become separated. There exist a great number of parts, such as the serous membranes, the cellular tissue, the tendons, the aponeuroses, the fibrous membranes, &c., in which we cannot distinguish the red blood, and where the capillary vessels contain only serum. This division of the elements of the blood is only found in a state of health. When the parts just mentioned become diseased, it often occurs that their small vessels are filled with red blood.

It has been attempted to explain this analysis of the blood in the small vessels. Boerhaave, who admitted the existence of several kinds of globules of different sizes in the blood, asserts that globules of a certain size can only pass into vessels of a given calibre. We have already seen that the globules as described by Boerhaave do not exist. Bichat believed that there existed in the small vessels a peculiar sensibility, in consequence of which they would receive only that part of the blood adapted to them. We have already frequently combated ideas of this kind; they are not admissible here, because the most irritating fluids, when introduced into the arteries, pass immediately into the veins, without their passage being opposed by the capillary vessels.

One of the most singular ideas that has ever entered the ima-

* See the experiments of Legallois.

ginations of physiologists is, that living bodies are not subject to physical laws; that life is in constant opposition to these laws: as if such opposition were possible; as if one phenomenon could be opposed to another. It is on this principle, which is repugnant to common sense, that the influence of weight, and the different positions of the body upon the circulation, has been but little studied. However, there can be no doubt of the existence of such influence, and that it is very great. Both medical and surgical empiricism is forced to recognise it. In many cases it is quite evident that the blood moves with more difficulty when propelled against its own weight; while, on the other hand, it passes more easily to those parts where it is carried by its own weight.

During sleep, and in the horizontal position, the blood is more freely directed towards the head. Dr. Bourdon remarked in himself that, when lying upon one side, the blood accumulated in the more dependant part of the head, swelling the pituitary membrane on that side, and intercepting the passage of air in the corresponding nostril. When he turned to the opposite side, the obstructed nostril became free, while that on the opposite offered the same phenomenon.

Thus the powers which circulate the blood have often to overcome the weight of the fluid, while universal gravitation exercises a remarkable influence over the circulation. This fact merits the attention of physicians; for, however slightly the functions are deranged, the effects of physical laws become manifest.

In traversing the small vessels, the blood is deprived of its elements; sometimes the serum escapes, and spreads itself over the surface of the membrane; at others, the fat is deposited in its cells; here it is the mucus, there the fibrine; and, besides, there may be foreign substances that have become accidentally mixed with the arterial blood. By losing these different elements, this fluid approaches the character of venous blood. At the same time that the arterial blood supplies those parts which are lost, the small veins absorb the substances in contact with them. For example, in the intestinal canal they take up the drinks; on the other hand, the lymphatic trunks pour the lymph and chyle into the venous system. It is certain, therefore, that the venous blood cannot be homogeneous, and that its composition must vary in the different veins. But having arrived at the heart by the motions of the right auricle and ventricle, and the disposition of the fleshy columns, all its elements become intimately mixed before it passes into the pulmonary artery.

There is a general law of the economy, that no organ can continue to act unless it receives arterial blood; the result, therefore, is, that all the functions are dependant upon the circulation. But, in its turn, the circulation is dependant upon respiration, which forms the arterial blood; nor can it exist without the action of the nervous system, which has a great influence upon the rapidity and course of the blood, and its distribution to the organs. In fact, under the influence of the nervous system, the motions of the heart

increase or diminish, and, of consequence, the general course of the blood is increased or retarded. Again, when the organs act voluntarily or involuntarily, observation shows that they receive an increased quantity of blood without the general circulation being at all accelerated; if their action be very considerable, the arteries leading to them have their action increased; if, on the contrary, their action diminishes, the arteries are retracted, and only allow a small portion of blood to arrive at the organ. These phenomena are manifest in the muscles; the circulation becomes more rapid when they contract; if they often contract, these arteries increase in volume; if they are paralyzed, the arteries become very small, and the pulse scarcely perceptible.

The nervous system, then, influences the circulation in three different ways. First, in modifying the motions of the heart. Second, in modifying the capillaries of the organs so as to accelerate or retard the course of the blood. Third, in producing the same effects in the lungs, that is, in rendering more or less easy the course of the blood through these organs. The acceleration of the motions of the heart becomes perceptible to us from the pulsation of its apex against the walls of the chest; an obstruction in the capillary circulation is known by a sensation of numbness, and a particular sort of pricking. When the pulmonary circulation is difficult, we are aware of it from a sense of oppression or suffocation. It is probable that the distribution of the filaments of the great sympathetic nerve to the walls of the arteries answers some important purpose, but we are completely ignorant of their use; experiment has thrown no light upon this point.

The composition of the blood must exercise great influence upon the mode of action of the organs; but we have still very imperfect notions of the chemical variations that this liquid undergoes. According to some works upon the blood, this fluid is always the same. It is probable that the progress of animal analysis will soon lead us from these imprecise ideas; some facts, at least, seem to indicate this. If we introduce into the jugular vein of a dog a few drops of water which has remained a little time in contact with animal substances in a state of putrefaction, in the course of an hour after the introduction the animal will be depressed, and lie down. Soon he will be attacked with an ardent fever; will vomit black and fetid matter; his alvine evacuations will be similar; the blood will have lost its power of coagulation, will be extravasated into the tissues, and death will soon follow.

These phenomena, which are very analogous to certain diseases of the human subject, as the black vomit in yellow fever, &c., appear to originate in an alteration in the composition of the blood. I think, even, that I have discovered that the dimensions of the globules diminish in proportion as these symptoms become developed. This is in harmony with the passage of the blood through the walls of the small vessels, and the hemorrhages which are its effect.

There is one mode of alteration that may be easily appreciated,

I mean the respective proportions of the serum and coagulum. I wished to see what would be the effect upon an animal to gradually diminish the solid and insoluble portion of the blood. For this purpose, I took a healthy dog and bled it eight ounces. The blood, when examined the next day, had but little serum; about one eighth part. I replaced the blood drawn, by injecting about half a pound of water into the jugular vein. The next day I repeated the bleeding and injection; the blood was now one fourth part serum, and three quarters coagulum. Two days afterward I repeated the same processes, and continued in this way every two days until the tenth day. Then there was three fourths serum and one fourth coagulum; the animal had become weak, moved with difficulty, appeared to have lost his instincts and caressing habits, his cerebral faculties were diminished and stupified; indeed, he was no longer the same animal.

No doubt, then, a certain composition of the blood is one of the conditions important to the exercise of the different functions.

These remarks induced me to try the injection of warm water into the veins in the human subject. The individual on whom I made this experiment was labouring under hydrophobia, and at the point of death. The introduction of a pint of water calmed his fury as if by enchantment.—(See *Journal de Physiol.*, t. iii.)

Of the Influence of the Inspiratory and Expiratory Muscles upon the Motion of the Blood.

We have demonstrated that the heart is the principal agent of the circulation. For the most part, its contractile force determines the progression of the blood; but there are other auxiliary powers which often intervene with great energy, and which exercise a great influence over the course of the blood, so as to suspend it completely. These powers are those which draw in and expel the air from the chest.

During the dilatation of the thorax, the blood of the venæ cavæ superior and inferior, and proportionally that of the other veins, is attracted towards the heart. The mechanism of this attraction is similar to that of the air in the lungs; it is, if we may be allowed the expression, *an inspiration of venous blood.* On the contrary, during expiration, all the pectoral organs being compressed, the venous blood is repelled; it flows back in the veins towards the organs, and the arterial blood arrives at its destination with the more promptitude, because to the pressure of the left ventricle is added that of the expiratory muscles.

These different phenomena are not striking in a quiet state, but when the respiration is forced, in the great muscular efforts which often accompany it, they are very remarkable.

The knowledge of these facts is derived from the labours of Haller, Lamure, and Larry; it supplies the means of explaining many phenomena which have much embarrassed physiologists. I now propose to enter into some details, in consequence of the great importance of the subject.

If we observe for some time the external jugular vein of one whose neck is very thin; or, what is still better, lay bare this vein in a dog, it will be very obvious that the blood moves through its cavity under very different influences. In general, when the chest dilates to inspire, the vein will be seen to be suddenly emptied; its walls will be flattened, and in contact. The vein on the other hand, swells, and is filled with blood when the chest contracts. These effects are more striking as the respiratory movements are more marked. Those of expiration are most remarkable when the animal struggles.

The respiratory actions are not the only causes of the motion of the blood in the jugular veins. With a little attention, we may perceive that the contractions of the right auricle sensibly influence it; they produce a sort of irregular palpitation in the vessels.

When the auricle contracts, the blood is repelled towards the head; on the contrary, it is attracted towards the heart by its dilatation. When there is an accidental coincidence of the dilatation of the chest and the auricle, or of the contraction of these parts, the movement of the blood in the jugular is regular; *i. e.*, the vessel is emptied and filled suddenly. But as the motions of the auricle are much more frequent than those of the thorax, it necessarily happens that this coincidence frequently does not exist; hence the beatings of the jugular are very irregular. This phenomenon is especially observed in very severe diseases, and was called by Haller the *venous pulse.*

The explanation of these phenomena, as given by Haller and Lorry, is very simple and satisfactory. When the chest is dilated, it *inspires*, or *sucks up* the blood from the venæ cavæ and the other veins. The mechanism of this *inspiration* or *motion* is nearly the same as that by which the air is drawn into the trachea. When the chest contracts, on the contrary, the blood is crowded back into the venæ cavæ in consequence of the pressure that all the pectoral organs, the heart, blood-vessels, and lungs, necessarily undergo during expiration. Hence the alternate fulness and emptiness of the jugulars.

To prove that this phenomenon is exactly in relation with a similar phenomenon which takes place in the venæ cavæ, I introduced a gum-elastic sound into the jugular vein until it reached the vena cava, or even the right auricle of the heart. I found that the blood escaped from the extremity of the sound only at the period of expiration. On the contrary, during inspiration the air was suddenly drawn into the heart, and gave rise to certain accidents that will be hereafter mentioned. The same results were obtained by passing the sound through the crural vein towards the abdomen.

There can be no reasonable doubt, then, of the modifications that respiration exerts upon the blood in the principal venous trunks.

We may also easily discover that expiration sensibly accelerates the movement of the arterial blood, by opening an artery in

one of the extremities. This is especially observable when the animal struggles and makes strong expiratory efforts. As we cannot always induce the animal to make these expiratory efforts at our will, we may have recourse to the process recommended by Lamure, *i. e.*, compress the sides of the thorax with the hands. On doing so, we shall see the arterial jet of blood enlarge or diminish in proportion to the pressure exerted.

Inasmuch as respiration was observed to produce this effect on the course of the blood in the arteries, it seemed probable that it might influence the progress of the venous blood, not only through the medium of the veins, as we have already seen, but also through the arteries. I thought this conjecture worth testing by experiment.

I placed a ligature upon one of the jugular veins of a dog; the vessel was emptied below the ligature, and swelled very much above it. I then pricked slightly with a lancet the distended portion, so as to make a very small opening. I thus obtained a jet of blood that the ordinary movement of respiration did not sensibly modify, but which tripled or quadrupled in size when the animal made a vigorous effort.

It may be objected that the effect of the respiration was not transmitted by the arteries to the open vein, but by the veins which remained free, and which would have transported the blood repelled from the venæ cavæ towards the vein that was tied, by means of the anastomoses. It was easy to remove this difficulty.

The dog has not, like man, large internal jugulars, which receive the blood from the interior of the cranium. In this animal, the internal jugular is little more than a *vestigium*, the blood from the head and neck passing almost entirely by the external jugulars, which are very large. By tying at the same time both these veins, I was sure of preventing the reflux referred to, to a great extent. But so far from this double ligature preventing the phenomenon spoken of, the jet, on the contrary, was still more strikingly in accordance with the movements of the respiration; it was even obviously modified in ordinary respiration, which, as we have seen, did not take place with a single ligature. To render this still more evident, I might observe, the action of the crural vein, which, with its branches, is garnished with valves which may be said to oppose the reflux; if there was an increase of the jet during expiration, it is manifest that the impulsion must certainly come from the side of the arteries.

This result I uniformly found in many experiments. The crural vein being tied and pricked below the ligature, the jet was observed to increase sensibly in full expirations, and during the mechanical compression of the walls of the thorax with the hands. With the instrument of M. Poiseuille I recognised and obtained a sort of admeasurement of these phenomena.

These, as well as the preceding experiments, necessarily lead to a striking change in the explanation of the swelling of the veins

during expiration. According to Haller, Lamure, and Lorry, this swelling is the consequence simply of the crowding back the blood of the venæ cavæ into the branches which open into them, mediately or immediately. But it is now manifest that to this must be added the arrival into the veins of a larger quantity of blood coming from the arteries.

The same modification must apply to the motions of the brain in connexion with respiration. It is not necessary, then, to attribute the swelling of that organ, at the moment of expiration, to the mere reflux of the blood in the veins; nor its sinking, at the moment of inspiration, singly to the sucking up of the fluid towards the chest. But the influence of respiration upon the progress of the arterial blood, and of it upon the blood in the veins, through the medium of the arteries, must constitute an important element in that explanation.

It appears to me that we may comprehend the phenomenon in this way. At the moment of a strong expiration or effort, all the thoracic and abdominal organs are compressed; the arterial blood is driven forward, more particularly in the ascending branches of the aorta. The abdominal aorta is also compressed, and admits the blood with difficulty in proportion to the pressure it undergoes, as has been well described by Lorry. The blood thus arrives more abundantly at the head, and tends to pass more promptly towards the veins which return it to the heart, which would immediately take place if the veins were free. But so far from this, the pressure exerted upon the thoracic organs has caused a reflux of the venous blood in the vessels which contain it, though this retrograde movement does not extend very far, in consequence of the valves which oppose it.

But the blood which flows back in the veins soon meets with the blood which arrives from the arteries; the vessel becomes distended, and the course of the fluid in the veins is suspended. This is the simple explanation of the swelling of the brain.

We must also refer to these movements of flux and reflux of the blood, the entrance of the cephalo-rachidian fluid into the cavities of the brain through the opening of the fourth ventricle, and its passing out from these cavities. At the moment when the sinuses and rachidian veins are distended, the compressed liquid passes into the aqueduct, traverses the third ventricle, and soon reaches the lateral ventricles. Afterward it passes in an opposite direction, by the same route, at the instant of respiration or the sucking up of the venous blood.

But what takes place in the brain must also occur in the other organs, with modifications, as relates to the disposition of their sanguineous vessels. The whole of the medulla spinalis becomes enlarged, the spleen elongated, the face reddened and swollen during crying, prolonged running, muscular efforts, and violent passions. The veins of the extremities swell under the same circumstances, and if you induce a person while bleeding to breathe strongly, the jet of blood sensibly augments. An individual suf-

fering with a phlegmon of one of the limbs experiences more vivid pain in the diseased part, on lifting a weight, running or crying, &c. All these phenomena, and many others analogous to them, depend evidently on the accumulation of blood in the organs during expiration, which urges forward the arterial, and opposes the return of the venous blood.

It results from these facts, that one of the consequences of great expirations and violent efforts is the more or less prolonged suspension of the circulation, which is more or less complete as the expiration or effort is more violent. Hence, probably, the impossibility of continuing great efforts beyond a few seconds, and the necessity of profound inspirations immediately afterward. Many circulatory phenomena appear to be connected with this momentary stagnation of the blood in the tissues; as apoplexies, nasal and other hemorrhages, sometimes the consequence of violent efforts; copious perspiration of tumblers after their exertions; the sudden headaches which follow defecation in some individuals; priapism observed in persons executed by hanging, &c.

It is not necessary that the glottis should be completely closed in order that the effects of expiration become manifest, as some have supposed; for considerable efforts often take place concurrently with cries forming grave sounds, which permit an easy issue to the expired air. We have demonstrative proof of this in the practice of veterinary surgeons, who often introduce a large metallic canula between the thyroid and cricoid cartilages of horses, in order to render their respiration easier. Though the passage to the lungs is thus kept constantly free, these animals are still enabled to continue their laborious employments. Another proof may be drawn from experiments in which we compress the sides of the thorax with the hands, and thus accelerate the course of the arterial or venous blood. In this case there is no indication of the glottis being closed when the thorax is compressed. I am farther assured of this by the following experiment: I made an opening into the trachea of a dog more than an inch in length, and from four to five lines in width. I then tied one of the jugular veins, and made a small opening above the ligature, through which there passed a continued jet of venous blood. This jet was considerably increased whenever the animal struggled or the thorax was compressed.

In terminating this article, I may remark, that the different phenomena above described are more apparent in proportion to the quantity of blood. If studied in an animal that has naturally but little blood, or which has lost a considerable quantity, they will be recognised with difficulty, and their reality appear doubtful, as has actually happened to some highly-respectable observers. But if we inject a suitable quantity of water into the circulatory system, all these phenomena become sufficiently palpable. This fact, which I have repeatedly demonstrated in my courses of lectures, is important to be remembered as respects the phenomena that have been thus described. It furnishes another

proof of the great caution necessary to be observed in noting all the physical circumstances that may influence the results when we undertake to investigate an animal function.

Of the Transfusion of Blood, and the Infusion of Medicinal Agents.

Such is the opposition that men of genius have always met from their contemporaries, that it was thirty years before the discovery of Harvey was acknowledged, though the proofs were then most evident. But as soon as the circulation was admitted, a sort of delirium seems to have seized upon the profession; it was supposed that the means of curing all diseases, and rendering man immortal, were discovered. The causes of all our diseases were attributed to the blood. To cure them, therefore, nothing more was supposed to be required than to remove the bad blood, and to replace it with that which was pure, taken from a healthy animal.

The first attempts were made upon animals, and were very successful. A dog having lost a large quantity of blood, received by transfusion that of a sheep, and was perfectly restored; another dog, old and deaf, recovered by these means the use of his hearing, and seemed to renew his youth. A horse twenty-six years old, having received into his veins the blood of four lambs, acquired new vigour. The experiment of transfusion was now tried upon man. Denys and Emerez, the one a physician, and the other a surgeon, of Paris, were the first who made the attempt. They introduced into the veins of an insane young man the blood of a calf, in a larger quantity than had been taken from him; he recovered his reason. A case of leprosy, and a quartan fever, were cured by these means; and many cases of transfusion were tried upon men in health without any injurious results.

But some sad accidents soon calmed the general enthusiasm excited by these few successful cases. The young man, soon after the experiment, became frantic; he was the second time subjected to transfusion, and soon died with a discharge of blood, and in a state of stupor. A prince of the blood royal having also fallen a victim to this practice, it was forbidden by the Parliament of Paris. A short time afterward, G. Riva, having performed the operation of transfusion upon two individuals who died in Italy, the pope forbade it. From that period transfusion has been considered as not only useless, but dangerous; but as it seems to have succeeded in some cases, it would be an interesting inquiry for a person skilled in such experiments to pursue the subject farther. I have had occasion to make a certain number of these experiments, but have never known any instance where the introduction of the blood of one animal into the veins of another was attended by any serious inconvenience, even when the quantity of blood thus introduced was much greater than before.

But in order that the transfusion may be made without incon-

venience, it is necessary that the blood should be passed immediately from the animal that gives to that which receives it. If the blood be first received into a vessel or syringe, and afterward injected, it will be more or less coagulated, and often becomes the cause of death by choking up the pulmonary vessels. All the experiments where this circumstance is not taken in the account have little value. I have seen the transfusion fail and cause death because the blood had to traverse a small tube two inches long, where it partly coagulated before passing into the new circulation.

A short time after the discovery of the circulation, it was attempted to introduce medicines directly into the veins. Some advantages resulted from it in some instances, and inconveniences in others, and it soon fell into discredit; but it has been tried with success in some experiments upon animals. It is an excellent way of judging promptly of the mode of action of a medicine or poison. This process is employed in administering medicine to large animals, in the Veterinary School of Copenhagen; great benefit is found from the promptitude of its action, and great economy in the quantity of medicine employed.

An American physician has given to the world a striking example of his devotion to the progress of knowledge. He injected into his veins a certain quantity of castor oil; fortunately, there was some difficulty in the operation, or he would have been infallibly the victim of his love of science. We have already shown that viscid liquids, like oil, cannot traverse the pulmonary capillaries, but arrest the circulation, and cause immediate death. He estimated the quantity of oil introduced at about two drachms. During the first few minutes Dr. Hales experienced no remakable sensation.

"The first extraordinary sensation that I observed," says he, "was an oily taste. A little after twelve, while washing the blood from my hands, and while conversing in very good spirits, I experienced a little nausea, with eructations and rumbling of the bowels; soon after a singular sensation, but which it is impossible for me to describe, appeared to me to mount suddenly to my head. At the same time I perceived a slight rigidity in the muscles of the face and jaw, which cut short my speech, accompanied with a sense of alarm and slight faintness. I sat down, and in a short time I felt better. By a quarter past twelve o'clock, I had a good deal of the oily taste, and some dryness of the mouth. I exposed myself freely to the air, and felt better; after having reposed for some time, my pulse was at seventy-five beats in the minute. At thirty-five minutes past twelve, the disorder of the bowels continued, and increased. I felt slight griping pains, as if I had taken a purgative; great nausea and vertigo; my arm felt stiff, but this I attributed to the bandage. At three quarters past twelve, the uneasiness of the bowels had much increased; the nausea was very great, and there was still the taste of oil; the mouth less dry; in five minutes after, urgent but ineffectual

desire for defecation, and slight pains in the head. At five minutes past one the pain of the bowels had augmented, and was much aggravated on pressure; the prompting to defecation urgent, without the power, the pain continued. At the end of two hours he felt better, and in the course of the day the more urgent symptoms gradually subsided. But he remained ill for three weeks, and did not recover for a long time his usual strength."

The injection of medicine into the veins is the only efficacious resource in certain extreme cases where the ordinary use of medicine is hopeless.

On the Introduction of Air into the Veins.

It is not easy to conceive by what inadvertence Bichat has repeated, in twenty places in his works, that a bubble of air accidentally introduced into the veins causes sudden death. This assertion is inaccurate. Any may satisfy themselves of this by forcing air into the veins with a syringe. This was announced by me as early as the year 1809, in a memoir read by me before the first class of the Institute. Since that time Nysten has published a memoir on this subject. He not only injected atmospheric air into the veins, but most of the known gases. He proved that most of the gases which are soluble in the blood, as oxygen and carbonic acid, may be thrown into the blood-vessels in considerable quantity, without serious inconvenience. On the contrary, that those gases which are insoluble often cause accidents and death.

In my lectures, I have frequently pointed out the difference in the results which arise according to the mode of introduction of air into the veins. If introduced slowly, no injurious effect is produced; if suddenly, the animal does not fail to experience a remarkable acceleration of the respiration. A peculiar sound is heard in the chest, the evident effects of the change the air undergoes in the venæ cavæ, the right auricle and ventricle, and the pulmonary artery, &c.; the animal shrieks and dies. The opening of the body shows the heart, especially the right side, the pulmonary artery, &c., very much distended with air or a light sanguineous froth, consisting chiefly of air. The same will be found in the cellular tissue of the lungs, where it produces emphysema of the organ, and in the arteries in all parts of the body, particularly the brain.

Some animals may receive enormous quantities of air into the veins without causing death. On one occasion I introduced with a syringe, with my whole strength and as rapidly as I could, from twenty to twenty-four pints into the veins of an old horse, without causing immediate death, though he ultimately sank. On opening him, we found the whole circulating system filled with air mingled with blood, and, what seemed quite remarkable, the lymphatic system distended with an enormous quantity of lymph, slightly yellow, and mingled with a little air. I have often since repeated this experiment, which seems to throw some light on the

lymphatic system, the uses of which are still but little understood. It would seem from this that it serves as a sort of reservoir, under certain circumstances, for the circulating system when too full. But in artificial plethora, that I have often produced by injecting water, I have never observed the distention of the lymphatic system.

These fatal effects of the sudden introduction of air into the veins has been often observed in man during surgical operations, especially where veins in or near the neck have been opened. At the moment of inspiration the external air is drawn into the vein in considerable quantity, and followed by sudden death. The opening of the body shows appearances like those above described. A similar accident not unfrequently happens in bleeding horses from the jugular vein; generally at the moment when the vein is in the act of being closed with a pin.

CHAPTER XVIII.

OF SECRETION, NUTRITION, AND THE GENERATION OF ANIMAL HEAT.

In traversing the innumerable small vessels by which the arteries and veins communicate, one part of the elements of the blood spreads itself over all the external and internal surfaces of the body; another is deposited in the small hollow organs situated in the substance of the skin and mucous membranes; a third is distributed to the parenchyma of those organs called *glands*, undergoes a particular elaboration, and is afterward poured out, under certain circumstances, on the surface of the mucous membranes or skin.

We give the generic name of *secretion* to that phenomenon by which a part of the blood escapes from the organs of circulation, and is afterward poured out, either externally or internally, whether it preserves its chemical properties, or whether its elements have undergone a new order of combinations. We generally distinguish the secretions into three kinds: the *exhalations*, *follicular*, and *glandular secretions.* But this division, as it respects secreting organs and secreted fluids, is very imperfect. Many organs which secrete cannot be referred either to follicles or glands; what are generally called follicles or glands are organs which differ so much from each other in their form, structure, and the fluids they secrete, that it would perhaps be best not to confound them under the same denomination. Nevertheless, to avoid anything like an unnecessary spirit of innovation, we shall hereafter speak of the secretions according to this classification. We shall not dwell on this article; for were we to allow it the extension of which it is susceptible, we should greatly exceed the bounds to which we have limited ourselves in this work.

Of the Exhalations.

The exhalations take place either within or without the body, upon the skin or mucous membranes. Hence their distinction into external and internal.

Internal Exhalations.

Wherever large or small surfaces are in contact, an exhalation takes place; whenever fluids are accumulated in a cavity without an apparent opening, they are deposited by exhalation; the phenomenon of exhalation also manifests itself in almost every part of the animal economy. It exists in the serous, synovial, and mucous membranes, the cellular tissue, the interior of the vessels, and the adipose cells, the internal parts of the eyes and ears, and the parenchyma of many organs, such as the thymus and thyroid gland, and the capsulæ renales, &c. It is by exhalation that the aqueous and vitreous humours, and the fluid contained in the labyrinth, are renewed. The fluids exhaled in these different parts have not all been analyzed; among those that have, many are found to resemble, more or less, the elements of the blood, and particularly the serum; such are the fluids of the serous membranes, of the cellular tissue, and chambers of the eye. Others differ more, *e. g.*, the synovia, fat, &c.

Serous Exhalation.

All the organs of the head, chest, and abdomen are covered with a serous membrane, which is also extended over the walls of these cavities, so that the organs are not in contact with the walls, or neighbouring viscera, except through the medium of this membrane. As this membrane is very highly polished, the organs can move easily upon each other and upon the walls. The principal cause that preserves the fine polish is the exhalation. There passes continually from every point of this membrane a very thin fluid, which spreads itself over the neighbouring parts, forming a humid coat, which favours the motion of the organs upon each other.

It appears that this power of gliding upon each other is very favourable to the action of the organs. Whenever they are deprived of this by disease of the serous membrane, their functions are disturbed, and sometimes cease altogether. In a state of health, the fluid secreted by the serous membranes nearly resembles the serum of the blood, with a certain quantity of albumen.

Serous Exhalation of the Cellular Tissue.

The *cellular tissue* is spread over almost every part of the animal economy. It serves sometimes to separate, and at others to unite different organs, and parts of the same organ. This everywhere consists of very small, delicate plates, crossing each other in a thousand different directions, so as to form cells. The size and arrangement of these plates vary in different parts of the

body. In some they are broad, thick, and form large cells; in others they are very small, thin, and form extremely small cells. In some places this tissue is very extensible; in others it is rigid, offering considerable resistance. But whatever may be the disposition of the cellular tissue, it exhales from its surfaces a fluid very analogous to that of the serous membranes, and which appears to serve the same purposes. Its use is to facilitate the motion of these membranes upon each other, and, of consequence, to favour the reciprocal motions of the organs and the changes of relation in their different parts.

Adipose Exhalation of the Cellular Tissue.

Besides the serosity, we find in the cellular tissue, in many parts, a fluid of a very different nature; this is fat. As respects the presence of fat, the cellular tissue may be divided into three kinds, viz., that which contains it constantly, that which contains it occasionally, and that in which it is never found. The orbit, the sole of the foot, the ball of the fingers and toes, are always found to exhibit fat. The subcutaneous cellular tissue, and that found on the surface of the heart, loins, &c., present it often; but that of the eyelids and scrotum, and interior of the cranium, never contain it.

The fat is contained in distinct cells, which do not communicate with the neighbouring ones. This has led to the belief that the tissue containing the fat differed from that containing the serum; but as no one has yet demonstrated these fatty cells, unless when filled with fat, this anatomical distinction appears to me to be very doubtful. The size, form, and disposition of these cells do not differ more than the total quantity of fat that they contain; in some individuals there are but a few ounces, while in others there are many pounds. From the experiments of M. Chevreul it appears that the human fat is almost always yellow; it is inodorous, and congeals at variable degrees of temperature. It is composed of two parts, the one fluid and the other concrete; which are again composed of two new immediate principles, but in different proportions, discovered by M. Chevreul, who calls them "*elaïne*" and "*stéarine*."

It is principally by its physical qualities that the fat appears to be useful in the animal economy. In the orbit it forms a sort of elastic cushion, upon which the eye moves with facility; on the sole of the foot and the nates it forms a cushion, which prevents the skin from being injured by the pressure of the body in standing or sitting. Its presence beneath the skin assists in giving rotundity to the form, diminishing the projection of the bones and muscles, and embellishing the body. As all fatty substances are bad conductors of caloric, it is useful in this respect, fat persons seldom suffering from cold in winter. Age and mode of life have a great influence on the production of this substance; young infants are generally fat. It is seldom that it is much developed in youth; but after the age of thirty, especially if the food be nutritious and

the mode of living sedentary, its quantity augments very much. The abdomen at this period becomes prominent, and the nates and mammæ in females become large. The yellow colour of this substance increases in old age.

Synovial Exhalation.

About the movable articulations we find a very delicate membrane, having great analogy to the serous membranes, but differing from them in having small reddish prolongations, containing numerous sanguineous vessels; they have been called *franges synoviales.* They are very visible in the large articulations of the extremities. It has been long believed by anatomists, and there are some who still think, that the capsules of the joints are folded over the movable cartilages, and cover the surfaces to which they correspond. I have lately satisfied myself that these membranes do not extend beyond the circumferences of the cartilages. We have spoken of the uses of the synovia in treating of motions.

Exhalation of the Interior of the Eye.

The different humours of the eye are also formed by exhalation. They are each enveloped by a membrane, which appears to be destined to exhale and absorb them. The humours of the eye are, the aqueous humour, at present supposed to be formed by the ciliary processes; the vitreous humour, secreted by the membrana hyaloidea; the crystalline; the black matter of the choroid coat, and that on the posterior surface of the iris.

The chemical composition of the aqueous, crystalline, and vitreous humours has been explained in the article *Vision.* The black matter of the iris and choroid coat has been analyzed by M. Berzelius. It is insoluble in water and acids; the caustic alkali dissolves it, and the acids precipitate it from this solution. It burns like vegetable matter, leaving a ferruginous cinder. Experience informs us that the aqueous and vitreous humours are rapidly renewed; when pus or blood have been extravasated into the eye, in a few days they disappear, and the humours resume by degrees their transparency. It does not appear that the choroid matter can be reproduced.

According to Messrs. Leroy d'Etiole and Coiteau, it would appear that the crystalline may be reproduced.

Exhalation of the Cephalo-Rachidian Fluid.

Among the most important and abundant, but least known of the exhalations, is the fluid which fills the *sub-arachnoidean cavity,* which extends to all parts of the encephalon, fills the inequalities of all parts of its surface, and which extends, with variable degrees of thickness, from the upper part of the cerebrum to the apex of the sacrum. We have already stated that this fluid passes into the ventricles of the cerebrum and cerebellum, traversing the opening situated at the lower extremity of the fourth ventricle, at

the part called by the ancient anatomists the *point of the calamus scriptorius.*

The quantity of the cephalo-spinal fluid varies according to many circumstances; this is mechanically necessary in the inverse proportion of the volume of the brain. When the latter is in a state of atrophy, this fluid occupies a considerable part of the cranio-spinal cavity. If one lobe be defective, as sometimes occurs in those in whom one arm or leg is contracted and paralyzed, this liquid fills the space which should have contained the deficient portion of the encephalon. I witnessed a case of this in a girl about fifteen years of age, in whom the cerebellum and pons varolii were completely wanting. Having extracted the cephalo-spinal fluid from a horse that had been killed, I placed it in the hands of M. Lapaigne for analysis; the following was the result:

Composition of 100 *parts.*

Water	98.180
Osmazome	1.104
Albumen	0.033
Chloruret of sodium	0.610
Subcarbonate of soda	0.060
Phosphate and traces of carbonate of lime	0.009

The soluble phosphorates and phosphates were unsuccessfully sought for in this liquid. The principal agent of secretion of this liquid is the vascular network which clothes the brain and spinal marrow, viz., the pia mater.

Sanguineous Exhalations.

In all the exhalations that we have now considered, only a part of the principles of the blood pass out from the vessels. The blood itself appears to be poured out into several of the organs, and to fill up the cellular tissue that forms their parenchyma; such are the cavernous bodies of the vagina and clitoris, the urethra and glans penis, the spleen and the mammary processes, &c. The anatomical examination of these different tissues seems to show that they are habitually filled with venous blood, the quantity of which differs in different circumstances, particularly according to the state of action or inaction of the organs. There exist many other exhalations of internal parts, among which I would mention the cavities of the internal ear, of the parenchyma of the thymus and thyroid gland, and of the capsulæ renales, &c. But we are scarcely acquainted with the fluids formed in these different parts; they have never been analyzed, and their uses are unknown.

Physiologists have often endeavoured to explain the phenomenon of exhalation. Indeed, each one has given his own opinion on this subject. Some admit the existence of *exhaling mouths,* others of *lateral pores.* Bichat has created particular vessels, which he calls *exhalants.* I say he has created them, for he ac-

knowledges that these vessels cannot be seen; as the existence of these pores, mouths, and exhalants are not sufficient to explain the diversity in the exhalations, they have been supposed to possess a peculiar sensibility and particular motions, in virtue of which they suffer certain parts of the blood to pass, and refuse a passage to the others. We have little to remark on such explanations.

It is very certain, however, that the physical disposition of the small vessels has an influence upon exhalation, as the following facts will show. When we inject, in the dead body, warm water into an artery passing to a serous membrane, as soon as the stream is established in the artery and vein, there will be seen upon the membrane a multitude of small drops, which evaporate promptly. Has not this phenomenon great analogy with exhalation? If we employ a solution of gelatin, coloured with vermilion, to inject a whole body, it frequently happens that the gelatin is deposited about the circumvolutions and inequalities of the cerebrum without the colouring matter having escaped from the vessels; the injection spreads itself, on the contrary, over the external and internal surface of the choroid coat. If we employ linseed oil, coloured with vermilion, we often find the colouring matter separated from the oil, and deposited in the synovial capsules of the large joints, while there is no transudation on the surface of the brain or the interior of the eye.

Is not this one of the true *post mortem* secretions which evidently depend on the physical arrangement of the small vessels? Is it not very probable that the same arrangement presides over exhalation, at least partly, during life?

The theory of exhalation has necessarily changed its aspect since the imbibition of the tissues has been recognised as an established doctrine. Before seeking in this phenomenon the special influence of life, or, in the received language, *the effect of the vital properties*, we must begin with the examination of the physical influences.

Now we know, by experiment, that the sanguineous and other vessels may be traversed from within outward, or from without inward. M. Fodera has made many experiments which leave no doubt on this point. A poisonous substance was introduced within an artery which was tied above and below. In a short time the poison was imbibed by the walls of the vessel, spread outward, and the animal was suddenly killed. If it had been possible to repeat this experiment on the small vessels, there can be scarcely a doubt that the result would have been still more rapid.

The primary physical cause of exhalation is probably the same, then, as that of absorption. Another cause is the pressure the blood undergoes in the circulatory system. This pressure must powerfully contribute to the passage of the more fluid or aqueous part of the liquid through the walls of the vessels. This phenomenon is easily seen after death, or even during life. If we push forcibly with a syringe an injection of water into an artery, the

whole surface of the part to which the vessel is distributed, including its trunk and branches, allows the injected liquid to ooze out, more or less freely, according to the force with which the injection is pushed.

Another mode of exhibiting this curious phenomenon is to inject into the veins of an animal a sufficient quantity of water to double, or even triple the usual volume of its blood. You will thus produce considerable distention of its circulating organs, and of course, by so much, augment the pressure upon the circulating liquid. Examine, then, a serous membrane, the peritoneum, *e. g.*, and you will see the serosity rapidly ooze out from its surface and accumulate in the cavity, producing under your eyes a true dropsy. I have even seen the colouring matter of the blood escape from the surface of some of the organs, as the liver, spleen, &c.

This happens when the veins are compressed, as in œdema and serous extravasations, and no doubt from a similar physical cause. In a word, every cause that increases the pressure upon the blood increases the exhalation. I have often observed this increased exhalation in the vertebral canal, on the pia mater of the medulla spinalis, under the following circumstances. I have also remarked that the sub-arachnoidean cavity, in the living animal, is always filled by the cephalo-rachidean fluid. I have observed that, at certain moments when animals make violent struggles, this serosity sensibly increases. It may be seen oozing from the vascular ramifications which constitute the proper envelope of the medulla spinalis. The same thing may also be seen on the surface of the brain, where there exists constantly a thin coat or layer of this liquid.

External Exhalations.

They consist only of the exhalations of the mucous membranes, and of the skin, or cutaneous transpiration.

Exhalations of the Mucous Membranes.

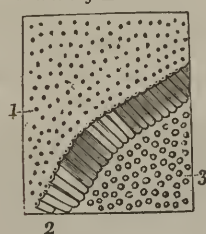
There are two mucous membranes: the one covers the surface of the eye, the lachrymal passages, the nasal cavities, the middle ear, the mouth, the whole of the intestinal canal, the excretory ducts, which terminate in it, and, lastly, the larynx, the trachea, and the bronchiæ; the other mucous membrane covers the surface of the organs of generation and the urinary apparatus. These two membranes are constantly lubricated by a fluid they secrete, called *mucus*. This fluid is transparent, viscid, and of a saltish taste; it reddens litmus paper, contains much water, muriate of potash, and soda, lactate of lime, soda, and phosphate of lime. According to Fourcroy and Vauquelin, the mucus is the same in all the mucous membranes. M. Berzelius thinks, on the contrary, that it varies much according to the parts from which it is taken. Many persons suppose that the mucus is formed exclusively by the follicles of the mucous membranes. I am satisfied, however, by recent experiments, that it is formed in the parts where the follicles

do not exist; I have also remarked, that it continues to be formed for some time after death. This merits the particular attention of chemists.

[The secretions which cover the mucous membranes appear to be derived from different structures. The glands of the mucous membrane of the intestinal canal have been distinguished by Müller into three kinds, viz., the glands of Lieberkuehn, Brunner, and Peyer.

1st. The *follicles of Lieberkuehn* are foramina or depressions so small as not to be visible without the aid of a glass, which are spread over the whole extent of the mucous membrane of the small intestines, and are so numerous that, when sufficiently magnified, they give to the membrane the dotted appearance of a sieve. The accompanying figure represents the appearance of these follicles.

(Fig. 39.)
Follicles of Lieberkuehn.



1. Are the openings on the surface. 2. The follicles themselves seen in a perpendicular section. 3. The surface of the cellular membrane, with pits for the closed extremities of the follicles.

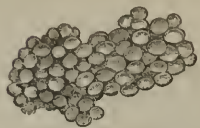
These structures, like those of Brunner and Peyer, are changed in typhoid fever. The annexed figure represents a magnified portion of the mucous membrane in fever, after Bœhm.

(Fig. 40.)
Mucous Membrane in Fever, with the Follicles of Lieberkuehn filled with tenacious white Secretion.

The *second kind* are the glands of Brunner. These follicles are visible to the naked eye, are distributed singly, and are most numerous in the upper part of the small intestines, especially the duodenum. They are sometimes called the *glandulæ disgregatæ.* These glands are deposited in the submucous tissue; their size in health is scarcely that of a hemp seed, and their structure is conglomerate and very complex.

The following figure represents one of these conglomerate mucous glands from the duodenum, magnified one hundred times, after Bœhm.

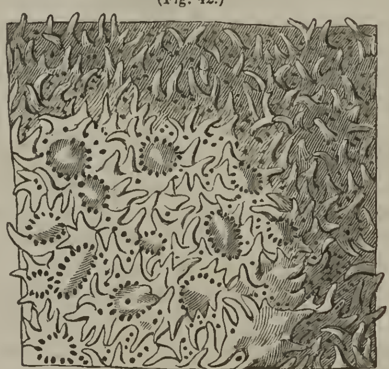
(Fig. 41.)
Gland of Brunner.



The third kind of mucous glands found in the alimentary canal are *the glands of Peyer*, or the *glandulæ agminatæ.* They are chiefly found at the lower portion of the ilium. They are here collected into clusters, or patches, assuming an elliptical form, called from this circumstance by the French *les plaques elliptiques.* Below is a magnified representation of one of these elliptical patches, after Bœhm. In this view we see also the follicles of Lieberkuehn, the small black dots, and the villi which cover the mucous coat.

These structures have become particularly interesting from the changes which are found to take place in them with great uniformity in typhoid fevers and some other diseases.

(Fig. 42.)



These oval patches are found on the side of the tube opposite to the mesentery. Their precise nature and uses are unknown, though it is probable that, with the other innumerable glandular structures with which the surface of this membrane is covered, one of their functions is to supply mucus to the canal. They are particularly liable to both acute and chronic diseases; care is therefore required to select those subjects for their examination in which this part is perfectly healthy. It appears, from the investigations of Bœhm and Müller, that in this state, if carefully washed and observed with a good magnifying-glass, they present an appearance thicker than other portions of the canal, owing to the size and number of the villi, which are broader here than in other parts, particularly at their root. The mucous membrane between the villi presents here, as in other parts of the intestines, the numerous follicles of Lieberkuehn; but, in addition to these, there are circular white spots, about one line in diameter, in which the mu-

cous membrane is free from villi; on very few there are traces of very short villi. In the human subject these spots are slightly raised. Each of these white spots, of which there are several in a patch of the glands of Peyer, is surrounded by a zone of openings like the follicles of Lieberkuehn, presenting in the plate an appearance of small dots. No secretion can be expressed from these white bodies. On rupturing them, a cavity corresponding to their size is found, containing a white, grayish mucus. The appearance of cells or follicles about this part is a morbid appearance, and only occurs, according to Müller, after the delicate membrane which covers this cavity has been destroyed, as is frequently observed in disease. In most cases of acute and chronic diarrhœa, but especially in typhoid fevers, these structures are found diseased. Modern observations have gone far to show that in the latter the glands of Peyer are diseased from the commencement of the fever, and only restored with the restoration of the general health.

A fourth variety of the mucous glands of the intestines are sometimes described under the name of *solitary glands.* By some physiologists they have been considered as identical with the glands of Brunner. According to Bœhm, they are single sacculi, similar to those which, when aggregated, form the patches of Peyer. They are surrounded with a zone of openings, contain a white matter, and become diseased in the same class of cases as the glands of Peyer. They chiefly differ from them in being beset with villi. The accompanying figure is a magnified view of one of these solitary glands, with its openings and villi, after Bœhm.

(Fig. 43.)
Solitary Gland or Sacculus.

When the mucous membrane of the small intestines is inflamed, as in typhoid fevers, the villi become prominent and the follicles of Lieberkuehn become evident, in consequence of their being filled with an opaque, whitish secretion.*]

The mucus forms a covering of various degrees of thickness on the surface of the mucous membranes, and is frequently renewed. Its water evaporates under the name of mucous exhalation. It protects the membrane from the action of the air, aliments, and various glandular fluids; it seems, indeed, to perform the same office for these membranes as the epidermis for the skin; independently of its general uses, its functions are modified according to the particular parts of these membranes. Thus, the nasal mucus assists the sense of smell; that of the mouth facili-

* Ed.

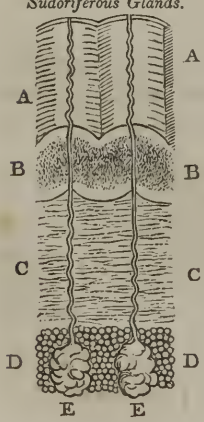
tates taste; that of the stomach and intestines concurs in digestion; and that of the genital and urinary passages assists in the functions of generation and urinary excretion. A great part of the mucus is absorbed by the membranes which secrete it; the rest is either thrown off alone, as when we spit, or is mixed with pulmonary transpiration, fecal matter, urine, &c.

Cutaneous Transpiration.

There is a transparent fluid, with an odour more or less strong, and of a salt and acid taste, constantly passing through the innumerable openings with which the epidermis is pierced. Most frequently this fluid evaporates as soon as it is brought in contact with the air; but sometimes it runs over the surface of the skin. In the first instance it is imperceptible to the sight; it is then called *insensible transpiration;* in the second, it is called *sweat.* Whatever may be the form assumed by this fluid when it escapes from the skin, it is composed, according to M. Thenard, of a large proportion of water, a small quantity of acetic acid, muriate of soda and potash, a little phosphate of lime, an oxide of iron, and a trace of animal matter. M. Berzelius conceives the acid of the sweat not to be the acetic acid, but the lactic acid of Scheele. The skin also exhales an oily substance, and the carbonic acid.

[The sudoriferous glands are seated just beneath the cutis. The excretory ducts open by minute pores in the epidermis, which are seen in elevated lines on the skin of the palm of the hand and the sole of the foot; they penetrate the epidermis rather obliquely, so that a sort of valve is formed, which is lifted up by the excreted fluid. The ducts pass through the epidermis and cutis in a spiral direction, and then enter the glands, which consist of the convolutions of the ducts more or less subdivided, on which blood-vessels are distributed; when the epidermis is thin, the canal is straighter. The secretion by these glands appears to be continually going on.—(*Carpenter.*)

(Fig. 44.)
Sudoriferous Glands.



Opposite is a representation of two of the sudoriferous glands from the palm of the hand magnified 40 diameters, after Gurlt.

A A. The epidermis.. B B. The tactile papillæ. C C. The chorion. D D. The adipose tissue. E E. The two sudoriferous glands. The contorted tubes, or excretory ducts, are seen passing through the skin, and perforating the cuticle.]

A great number of experiments have been made to determine the quantity of transpiration formed in a given time, and the range of its variations under different circumstances. The first attempts of this kind were made by Sanctorius, who for thirty years, with extreme care and unwearied patience, weighed his aliments, drinks, solid and fluid

excretions, and afterward himself. But, notwithstanding his zeal and perseverance, Sanctorius never arrived at any very precise results. Since his time, the subject has been examined with more success; the most remarkable efforts on this subject were made by Lavoisier and Seguin. These gentlemen were the first who distinguished between the loss from pulmonary and cutaneous transpiration. Seguin enclosed himself in an oiled cloth bag that covered the head, with an opening for the mouth, the edges of which were made to adhere about the mouth by a mixture of pitch and turpentine. In this way the pulmonary transpiration alone escaped into the atmosphere. To ascertain the quantity, it was only necessary to weigh himself with the sack, at the beginning and end of the experiment, with a very delicate balance. By weighing himself out of the sack, he determined the total quantity of the transpired humour; so that, saying nothing of the fluid which he knew had passed out from the lungs, he was in possession of the quantity of humour exhaled by the skin. He kept, besides, an accurate account of his food, solid and fluid excretions, and, in general, of all those causes that might influence transpiration.

The following are the results of the inquiries of Lavoisier and Seguin:

1. The largest quantity of insensible transpiration, including that of the lungs, is thirty-two grains per minute.
2. The least loss was eleven grains in a minute.
3. During digestion, the loss of weight occasioned by insensible transpiration was at its *minimum.*
4. Immediately after dinner the transpiration was at its *maximum.*
5. The medium quantity of insensible transpiration was eighteen grains in a minute; of these, eleven depended upon cutaneous, and seven on pulmonary transpiration.
6. Cutaneous transpiration only varied during and after eating.
7. Whatever might be the quantity of food taken by any one, or whatever the variations of the atmosphere, the same individual, after having increased in weight to the amount of the whole quantity of food taken, returned every day, at the end of twenty-four hours, to nearly the same weight that he was before; provided that he was not at the time growing, nor had committed any excess.

It is to be regretted that this important undertaking was not continued, and that these authors limited themselves to the investigation of insensible transpiration, without extending their observations to the sweat. Whenever cutaneous transpiration is not reduced to vapour, as soon as it is brought in contact with the air, it appears on the surface of the skin in the form of a liquid; now this effect may occur either from the abundance of the transpiration, or from the dissolving power of the air being diminished. We sweat readily in a warm and moist atmosphere by the influence of these two causes, but we sweat much less easily

in a warm and dry air. Certain parts of the body transpire more abundantly, and sweat more easily, than others; such as the hands, feet, armpits, groins, forehead, &c. In general, the skin of these parts receives proportionally a much greater quantity of blood; and some of them, the armpit, sole of the foot, &c., are excluded from the air. The sweat does not appear the same in every part; every one knows that its odour varies in different parts of the body: the same is true of its acidity; this appears to be much greater in the armpits and soles of the feet than in other parts.

We have seen what influence the volume of the blood, its composition and compression in the vessels, exercise over the internal exhalations. The same circumstances act in an analogous manner on the cutaneous transpiration. Plethoric persons perspire freely; after the use of warm drinks, which are rapidly absorbed, the exhalation and transpiration equally increase. Lastly, continued exertion, as walking fast, running, &c., are followed by sweat, especially if the weather be warm. I am acquainted with a person who, when in bed, can sweat at will by contracting forcibly, for a short time, his muscular system.

Cutaneous transpiration has various uses in the animal economy; it preserves the softness of the skin, and is favourable to the sense of touch. By its evaporation, together with pulmonary transpiration, it is the principal means of cooling the body, and preserving it at a certain temperature. It would appear that its expulsion from the economy is very important, as, whenever it is diminished or suspended, derangement of the health follows; and many diseases do not yield until copious perspiration is produced.

Follicular Secretions.

We give the name of follicles to the small, hollow organs lodged in the skin and mucous membranes, and which have, for this reason, been distinguished into *mucous* and *cutaneous;* the follicles are also divided into simple and compound.

Mucous Follicular Secretions.

The simple mucous follicles are found, over nearly the whole extent of the mucous membranes, more or less abundant; there are, however, parts of these membranes, of considerable extent, where they cannot be detected. Those bodies called the fungous papillæ of the tongue, the amygdalæ, the glands of the cardia, prostate, &c., are considered by anatomists as collections of simple follicles. Perhaps this opinion is not well founded; we know little of the fluid they secrete; it appears to be analogous to the mucus, and to answer the same purposes.

Cutaneous Follicular Secretions.

In almost every part of the skin there exist small openings, the orifices of small, hollow organs, with membranous walls, habitually filled with albuminous and fatty matter, the consistence,

colour, odour, and even taste of which vary in different parts of the body, and are continually poured upon the surface of the skin. These small organs are called the follicles of the skin; there is at least one at the base of each hair; the hairs, indeed, often traverse the cavity of a follicle in passing out. The follicles form that shining, fatty substance that we see upon the scalp and cartilage of the ear. The follicles secrete the wax in the meatus auditorus externus, and likewise the thick, whitish matter that we force out from the skin of the face by pressing it, under the form of small worms. This substance, from its external surface being in contact with the air, becomes blackened, and produces the numerous spots that we see in the face of some persons, particularly about the nostrils and cheeks.

It appears, also, that these follicles secrete the white, odorous matter that is continually renewed about the parts of generation. From being spread upon the surface of the skin, hair, &c., this substance preserves the softness and elasticity of these parts, renders their surface smooth and polished, and favours their motion upon each other. In consequence of its unctuous nature, it in some measure defends them from humidity.

Glandular Secretions.

We give the name of *gland* to a secretory organ, which pours the fluid formed by it over the surface of a mucous membrane or the skin by one or more excretory ducts. The number of glands is very considerable; their action has received the name of *glandular secretion.* There are seven secretions of this kind; the tears, the saliva, the bile, the pancreatic juice, the urine, the semen, and the milk. We may, perhaps, add to these the secretions of the mucous glands and the glands of Cowper.

Secretion of Tears.

The gland that forms the tears is very small; it is situated in the upper and outer part of the orbit, and a little on the outside of the eye; it is composed of small granulated masses, united by cellular tissue. Its excretory ducts, small and numerous, pass out at the posterior part of the upper eyelid; it receives a small artery, a branch of the ophthalmic, and a nerve derived from the fifth pair. In health, the tears are not very abundant; the fluid is limpid, inodorous, and of a saltish taste. They were analyzed by Fourcroy and Vauquelin, who found them composed of a great proportion of water, some hundredths of mucus, and muriate, and phosphate of soda, a very little soda, and pure lime. What is generally called the tears is not entirely, however, the fluid secreted by the lachrymal gland; it is a mixture of this with the matter secreted by the conjunctiva, and probably that of the glands of Meibomius.

The tears form a covering to the conjunctiva of the eye, and defend it from the contact of the air; they facilitate the motion of the eyelids upon the eye, favour the expulsion of foreign bodies,

and prevent the action of irritating substances upon the conjunctiva; under these circumstances, their quantity becomes suddenly very much increased. They also assist in expressing the passions; disappointment, grief, joy, and pleasure cause the tears to be poured out in abundance; their secretion, it is manifest, is strongly influenced by the nervous system. This influence takes place, probably, through the medium of the nerve sent to the lachrymal gland from the fifth pair of cerebral nerves.*

Secretion of the Saliva.

The salivary glands are, first, the two parotids, situated before the ear, and behind the neck and ascending process of the inferior maxillary bone; second, the sub-maxillary gland, situated beneath and on the surface of this bone; third, the sub-lingual, placed immediately below the tongue. The parotids and sub-maxillary glands have each only one excretory duct; the sub-linguals have several. All these glands consist of granulated masses, of different forms and sizes. They receive arteries of considerable size, in proportion to their volume, and are amply supplied with nerves derived from the brain and spinal marrow. The saliva secreted by these glands is continually running into the mouth, and occupies its lower part. It is placed between the anterior and lateral parts of the tongue and the lower jaw at first, and when this space is filled, it is lodged between the inferior lip, the cheek, and the external side of the lower jaw. When deposited in the mouth, it becomes mixed with the fluids secreted by the mucous membrane and follicles.

No one has ever analyzed the fluid of the salivary glands separately, but only the fluid found in the mouth, which is, no doubt, almost entirely composed of saliva. It is limpid, viscid, without colour or smell, of a bland taste, and somewhat heavier than water. Berzelius asserts that it is composed of 992.9 of water, 2.9 of a particular animal matter, 1.4 of mucus, 0.7 of muriate of potash and soda, 0.9 of tartrate of soda and animal matter, and 0.2 of soda. It is probable that the composition of the saliva varies, as it is sometimes sensibly acid.

We owe to M. Mitscherlich, a learned physician and skilful chemist, a curious analysis of the saliva taken from an accidental opening in the parotid gland. The same author has also made many interesting remarks on the secretion of the saliva itself. The following are some of them.

The quantity of saliva is by so much the less as there is a large quantity of aliments introduced within the mouth. The motion of the jaws increases the afflux of the fluid. During quiet sleep, the parotid secretes so little that it is impossible to collect any. During speech, M. Mitscherlich collected from his patient, in the course of a few minutes, several drops of very limpid saliva. In twenty-four hours the fistula furnished from sixty-five to ninety-

* See, for the other uses of the tears, article *Vision.*

five drachms of saliva, varying according to the nature of the aliments.

The saliva was most frequently found slightly acid; sometimes it was strongly alkaline; at others, neutral. During the intervals between eating, it was acid; while eating, it became alkaline. The acidity was often observed to disappear with the first mouthful of aliment. The saliva contained hydrochloric, sulphuric, and phosphoric acids, but not sufficient to neutralize the alkali.

The saliva is one of the fluids most useful in digestion; it favours the mastication and division of the aliments; it assists in deglutition and the formation of chyme, and facilitates the motion of the tongue in speech and singing. The greater part of this fluid is carried into the stomach by the action of deglutition; a small part passes out with the expired air, and evaporates.

[The structure of the salivary glands and pancreas in man bears considerabe resemblance to that of the mammæ. The following figure represents a lobule of the parotid gland of a newborn infant injected with mercury. It is magnified fifty diameters.]

(Fig. 45.)
Lobule of Parotid Gland.

Secretion of the Pancreatic Juice.

The pancreas is situated in the abdomen, behind the stomach; its excretory duct opens into the duodenum near to that of the liver. From the granulated structure of this organ, it has been considered a salivary gland; but it differs from them in the small size of the arteries it receives, and from its not having any cerebral nerve.

De Graff, the celebrated Dutch anatomist, discovered a mode of collecting the pancreatic juice; it consisted in introducing into the intestinal extremity of the excretory duct the barrel of a small quill, which terminated in a little bottle, placed in the abdomen of the animal. I have often attempted to repeat this process, but have always failed. The quill, and every other tube, wounded the mucous membrane of the duct, and the blood, oozing out, gradually closed up the mouth of the tube. I had, therefore, recourse to a much more simple method; having laid bare the orifice of the duct in a dog, I wiped carefully, with a piece of fine linen, the sur-

rounding mucous membrane, and then waited until a drop of the juice passed out. As soon as it appeared, I sucked it up by means of a peculiar sort of pipe (*pipette*), an instrument used in chemistry. In this way I have been able to collect several drops of this fluid at a time, but never a sufficient quantity to make a regular analysis. I have found it of a light yellow colour, of a saltish taste, and without odour; it possessed alkaline properties, and was partly coagulated by heat.* The circumstance which has appeared the most remarkable to me in endeavouring to procure this fluid, is the small quantity which seems to be secreted. It frequently happens that a drop will not pass out once in a half hour; and I have sometimes waited for a much longer period before it has appeared. Its secretion does not seem to be increased during digestion, but, on the contrary, rather retarded. In general, I think it is most abundant in very young animals.

Messrs. Levret, Lassaigne, and Watrin have made some curious chemical researches on the secretion of the pancreatic juice in the horse.

Having placed a horse on his left side, they made an incision into the abdominal walls, and laid bare the duodenum. Having divided the intestine longitudinally, and penetrated into its cavity, they perceived two openings, through which there escaped two sorts of liquids. The one was of a yellowish green; the other less abundant, and colourless; the first, no doubt, was the bile; the other, the pancreatic fluid. They then introduced a sound of gum elastic into the duct of the pancreas, and secured it by a ligature. At the other end of the sound there was a gum elastic bottle, strongly compressed by a ligature, so as to expel all the air. When the sound was well secured in the pancreatic duct, the ligature about the bottle was removed, when, in consequence of its elasticity, the bottle expanded, thus causing a sort of sucking of the pancreatic juice favourable to the experiment. On detaching the bottle at the end of half an hour, it was found to contain about three ounces of a limpid, saltish, and alkaline fluid. Its specific gravity was 1.0026. This fluid, on being analyzed, contained,

Water	99.1
Animal matter soluble in alcohol The same in water . . Traces of albumen . . Mucus, free soda . . . Chloruret of sodium and potassium Phosphate of lime . .	0.9
Total	100.0

The same authors have tried the process of Graff and Schuyl upon dogs, but were not more fortunate than myself. They sat-

* In birds, which have two organs of this kind, I have remarked that the excretory ducts are endowed with a constant peristaltic motion. The pancreatic juice is also much more abundant; it is almost entirely albuminous; at least, it hardens like albumen, by heat.

isfied themselves that applying excitants, particularly weak acids, on the duodenal orifice of the pancreatic duct, produced promptly an abundant excretion of the pancreatic juice. Messrs. Tiedemann and Gmelin procured the pancreatic juice of a dog and a sheep by a process very analogous to that of De Graaf. The most important result at which they arrived was, that this fluid differs much in its chemical properties from the saliva, with which many physiologists had confounded it. Notwithstanding the importance of the researches that have been cited, and the light thrown upon the subject, still it must be admitted that, in the present state of knowledge, we are unacquainted with the uses of the pancreatic juice.

Secretion of the Bile.

The liver is the largest gland in the body; it differs from all the other secretory organs still more in being constantly traversed by a large quantity of venous blood, besides the arterial blood sent to this as to every other part. Its parenchyma does not resemble the other glands, and its secretions differ essentially from all other glandular fluids.

[When the liver is closely examined by the naked eye, it is found, according to Kiernan, to consist of small granular bodies, about the size of a millet-seed, of an irregular form, and presenting a number of rounded, projecting processes upon the surface. These are called *lobules* or *acini*. When longitudinally divided, they present a foliated appearance, from their connexion with the hepatic vein, which, passing into the centre of each division, is named the *intra-lobular vein*. The exterior of each lobule is covered by a process of the *Capsule of Glisson*, and its substance composed of the minute ramifications of the before-mentioned vessels, the spaces between which are filled up with a parenchyma composed of nucleated cells. The following figure, after Kiernan, shows this structure; thus it will be seen that each lobule represents the essential character of the whole gland.

Figure 46 shows the connexion of the lobules of the liver with the hepatic vein.

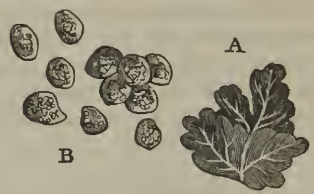
(Fig. 46.)

A is the trunk of the hepatic vein. B B B are the lobules depending from its branches, like the leaves of a tree, the centre of each being occupied by a venous twig; this is the *intra-lobular vein.*

Below is a magnified view of the lobules of the human liver, with ramifications of the hepatic vein, marked A. B indicates the nucleated cells, composing the parenchyma of the gland, as represented by Wagner.

(Fig. 47.)

Lobules of Human Liver.

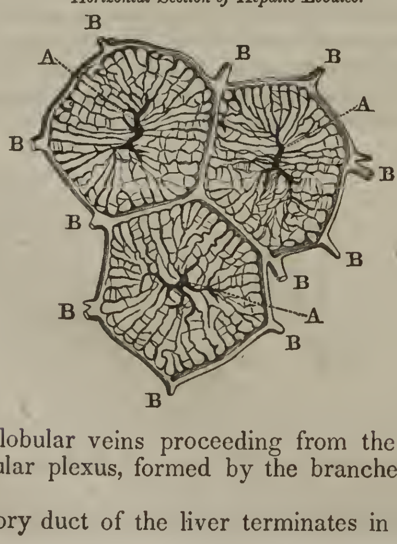


The lobules, when transversely divided, are found to present a somewhat pentagonal or hexagonal shape, rounded so as to form a series of passages or interlobular spaces. On these lie the branches of the vena porta, and of the hepatic vein, artery, and duct, from which are derived the plexuses that compose the lobules. Each lobule, when examined with the microscope, is seen to be apparently composed of numerous minute bodies, of a yellow colour and of various forms, called by Malpighi *acini.* The vena porta, it will be recollected, is found by the convergence of the veins, which return the blood from the chyloporetic viscera. —(*Carpenter.*)

The following is a magnified horizontal section, after Kiernan, of three superficial lobules, showing the *interlobular spaces*, and the two principal systems of blood-vessels.

(Fig. 48.)

Horizontal Section of Hepatic Lobules.



A A. Intra-lobular veins proceeding from the hepatic veins. B B. Interlobular plexus, formed by the branches of the portal veins.]

The excretory duct of the liver terminates in the duodenum,

but before reaching this part it communicates, by means of a small duct, called cystic, with a small membranous sac, called the *vesicula fellis*, which is almost constantly filled with bile. The cystic duct is garnished with a small spiral valve, discovered by M. Amusat. There are few fluids which so materially differ from the blood as the bile. Its colour is greenish; its taste extremely bitter; it is viscid, stringy, sometimes transparent and sometimes clouded. It contains water, albumen, a substance called by chemists *resin*, a yellow colouring principle,* soda, and salts, viz., muriate, sulphate, and phosphate of soda, phosphate of lime, and oxide of iron. These properties are particularly found in the bile contained in the gall-bladder. That which passes directly from the liver, and which is called the hepatic bile, has never been analyzed. It is not of so deep a colour, is less viscid, and less bitter than the cystic bile.

M. Lassaigne, who examined that extracted from a living dog, has not found it to differ from that taken from the gall-bladder. According to M. Thenard, 800 parts of the bile is composed of

Water	700.
Green resinous matter	15.
Picromel	69.
Yellow matter	00.
Soda	4.
Phosphate of soda	2.
Hydro-chlorate of potassa and soda	3.5
Sulphate of soda	0.8
Phosphate of soda and magnesia	1.2
Traces of oxide of iron	00.

M. Chevreul found in this fluid cholestrine.

The result of a great number of experiments by Messrs. Tiedemann and Gmelin is, that the bile in the human subject contains cholestrine, resin, picromel, oleic acid, a great quantity of matter soluble in water, colouring matter, mucus; and undoubtedly, add these authors, many other substances.

The formation of bile seems to be continual. Whatever may be the circumstances in which the animal is placed, if the orifice of the duct, called the ductus communis choledochus, be laid bare, we can distinguish this fluid passing drop by drop over the surface of the intestine. It appears that the gall-bladder becomes filled when the stomach is empty and the abdominal pressure least. It has always appeared to me to be more distended at this time, but it does not lose all its contents when the stomach is full. The circumstance which contributes most to the expulsion of the bile is vomiting. I have often found it flaccid in animals that had died from vomiting, the effects of poisons. But in no instance have I perceived indications of contractility either in the gall-bladder itself or the hepatic or cystic ducts,

* It is thought that the yellow colouring matter of the bile is the same as that of the serum and urine.

notwithstanding I have tried upon these parts all those excitants which cause intestinal and vesical contractions. In birds these parts are contractile.

With respect to the manner in which the bile passes from the liver towards the gall-bladder, and accumulates so as to distend it, this appears to be owing to the great contraction of the ductus communis choledochus at the moment it pierces the walls of the duodenum. The bile, thus meeting with an obstruction to its free discharge, undergoes a reflux motion through the cystic duct towards the gall-bladder, where it meets no obstacle. This effect is produced even in the dead body; if we push gently an injection through the hepatic duct, a part of the liquid passes into the intestine, and a part into the gall-bladder. It is probable that the spiral (spiroide) valve discovered by M. Amusat acts an important part, both in the entrance of the bile into the gall-bladder, and its discharge from that reservoir.

The liver receiving both venous blood from the vena portæ, and arterial blood by the hepatic artery, physiologists have anxiously inquired which of these two bloods serve for the formation of the bile. Many have said that the blood of the vena portæ, being more highly charged with carbon and hydrogen than that of the hepatic artery, was more suitable to produce the elements of the bile. Bichat combated successfully this opinion; he demonstrated that the quantity of arterial blood that arrived at the liver was more proportioned to the quantity of bile secreted than that of the venous blood; that the volume of the hepatic duct was not in proportion with the vena portæ; that the fat, a substance highly charged with hydrogen, was secreted with arterial blood. We do not take sides in this discussion; both opinions are equally destitute of proof. Besides, nothing is more probable than that both kinds of blood may serve in the secretion. Anatomy seems to indicate it; for injections show that all the vessels of the liver, arterial, venous, lymphatic, and excretory, communicate together.

The bile concurs in digestion in a very useful manner, though the mode is unknown. In our ignorance relative to the causes of diseases, we attribute to the bile injurious properties which probably do not exist.

Secretion of Urine.

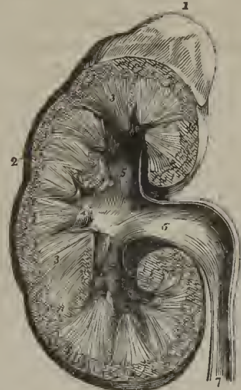
The secretion to which we are now about to call the attention of the reader differs in many respects from the preceding. The fluid which is the result of it is much more abundant than that of any other gland; and, instead of performing any farther uses in the economy, it is destined to be expelled. We are informed of the necessity of doing this by a peculiar sensation, which, like other instinctive phenomena of this kind, becomes very vivid and painful; if it be not satisfied promptly, its retention is accompanied by the most troublesome consequences. There are few of the organs of secretion so complicated as that of the urine. It is composed of the two *kidneys*, the *calices*, the *pelvis*, the *ureters*,

the *urinary* bladder, and the urethra. The abdominal muscles also concur in the action of these different parts; the kidneys alone secrete the urine; the others only serve the purposes of retaining, transporting, and expelling it.

[Organs destined to urinary secretion are found low in the scale of animals. The following figure is a representation of a vertical section of the kidney surmounted by the supra-renal capsule.

(Fig. 49.)

Vertical Section of Kidney.

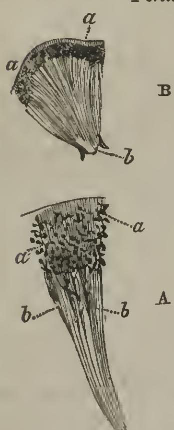


No. 1. The supra-renal capsule. No. 2. The vascular or cortical portion. No. 3. The tubular portion, consisting of cones. No. 4. The calices, receiving the apices of the corresponding cones. No. 5. The infundibula. No. 6. The pelvis. No 7. The ureter.

The cortical part of the kidney is very vascular; the plexus formed by the tubuli uriniferi coming into the closest connexion with the sanguiferous capillaries of this part. This appears to be the principal seat at which the process of secreting the urine takes place, the tubuli uriniferi conducting the secreted fluid towards the ureters. As the tubuli pass towards the cortical portion, they increase in number by divarication, their diameter remaining the same. When they arrive at the cortical substance, their previous straight direction is changed, and they become very much convoluted. The closeness of the texture formed by their interlacement with the blood-vessels renders it difficult to obtain a clear view of their mode of termination. There seems, however, no doubt that they inosculate with each other, forming a plexus, with a free extremity here and there. But the number of these free or cœcal extremities does not appear to be nearly equal to that of the uriniferous tubes themselves. Scattered through the plexus formed by the blood-vessels and uriniferous tubes, a number of little dark points may be seen with the naked eye, known as the *Corpora Malpighiana.* These, when examined by a high magnifying power, are found to consist of a convolu-

ted mass of minute blood-vessels, somewhat resembling the convolute masses of absorbents known as the *lymphatic glands.* It was at one time supposed that the uriniferous tubes arose directly from these bodies; but the careful examinations of Müller and Huschke have proved that the vascular bodies have no direct connexion with that system, being only capable of injection from the arteries or veins. Of their use nothing is positively known; it is evident, however, that they must have some special function, since they are found in the kidneys of all vertebrated animals. —(*Carpenter.*)

(Fig. 50.)
Portion of the Kidney in a New-born Infant, after Wagner.



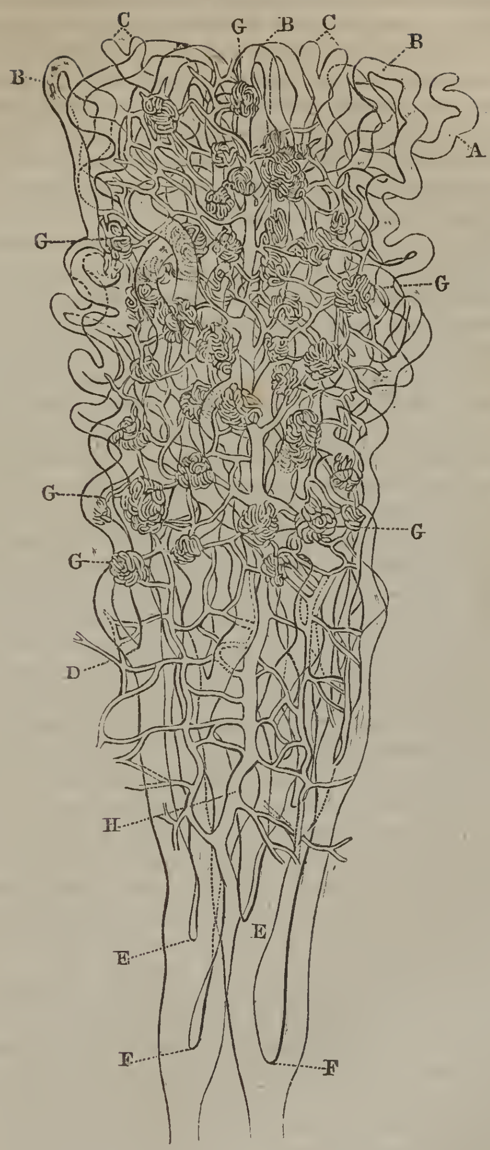
A. Of the natural size. *a a.* Corpora Malpighiana, as dispersed points in the cortical substance. *b b.* Papillæ. B. A smaller portion magnified. *a a.* Corpora Malpighiana. *b.* Tubuli uriniferi.

The walls of the tubuli uriniferi appear to be the parts in which the secretion takes place. When one of the cœcal extremities is examined with a high magnifying power, its mucous membrane is found to be covered with a layer of nucleated cells, forming an epithelium. The following is one of these cœcal extremities, from the kidney of an adult, magnified 250 diameters, after Wagner, showing the tesselated epithelium.

(Fig. 52.)
Extremities of Tubuli Uriniferi

The cut on the opposite page (fig. 51) is a representation of a small portion of the kidney magnified sixty times, after Wagner.

(Fig. 51.)



A is a cœcal extremity of a tubulus uriniferus. B B. Recurrent loops of tubuli. C C. Bifurcations of tubuli. D E F. Tubuli, converging towards the papillæ. G G G. Corpora Malpighiana, seen to consist of plexuses of blood-vessels connected with a capillary network. H. An arterial trunk.]

The *kidneys* are small in proportion to the quantity of fluid they secrete. They are generally surrounded with a large quantity of fat, and are situated on the sides of the vertebral column, before the last of the false ribs and the quadratus lumborum. Their parenchyma is generally composed of two substances: the exterior, which is very vascular, is called the cortical; the other part, called medullary or tubular, is arranged into a certain number of cones, the bases of which correspond to the surface of the organ, and the apices unite in a membranous cavity, called the pelvis. These cones appear to be formed by a large number of small hollow fibres, which are excretory ducts of a particular kind, and are constantly filled with urine. There is no organ which receives so much blood, in proportion to its volume, as the kidney. The artery is short and large, and arises directly from the aorta; it communicates very freely with the veins and tubular substance, as may easily be shown by injections of the coarsest kind, which, when pushed into the renal artery, pass into the veins and pelvis, after having filled the cortical substance. Filaments of the great sympathetic are the only nerves distributed to the kidney.

The calices, pelvis, and ureters form together a canal, which passes from the kidney, where it embraces the papillæ, and terminates in the bladder. This last organ is an extensible and contractile sac, destined to receive the fluid secreted by the kidney, and which communicates externally by a canal called the *urethra;* this is long in man, but short in the female. The posterior extremity of the urethra in man is surrounded by the *prostate gland*, which has been considered by some anatomists a mass of mucous follicles. Two small glands, placed before the anus, pour out a particular fluid into this canal. Two muscles descend from the pubis towards the rectum, pass along the sides of that part of the bladder which terminates in the urethra, approach each other posteriorly, and thus form an arch which embraces the neck of the bladder, and raise or depress it.

If we divide the pelvis of the kidney in a living animal, we can perceive the urine oozing out slowly from the papillæ; this fluid is deposited in the cavity of the calices, afterward in that of the pelvis, and gradually in the ureter, through which it at last penetrates to the bladder, into which it continues constantly to trickle, as it is easy to perceive in persons affected by a deformity, called a *retroversion of the bladder*, in which the internal surface of this organ is exposed to view. A slight compression of the papillæ forces the urine out in a considerable quantity, but instead of being limpid, as it is naturally, it is thick and turbid. It appears, therefore, to be filtered by the hollow fibres of the tubular substance. The passage of the urine into the bladder through the ureters is not constant; at regular and short intervals, the ureters, dilated by the urine, open at their vesical orifice, and allow the urine to pass. Sometimes it enters in a small jet at first, but afterward gradually oozes in. Then for a few seconds the ureters and their orifices sink down, and the discharge of urine ceas-

es. Generally, the entrance of the urine into the bladder takes place during inspiration. Neither the pelvis nor the ureter being contractile, it is probable that the force which determines its progress is partly that by which it is poured into the pelvis, and partly the pressure of the abdominal muscles; to which may be added, when the body is erect, the weight of the fluid.* Under the influence of these causes, the urine is introduced into the bladder, and by degrees distends this organ; sometimes to a considerable extent, the extensibility of its different membranes permitting this accumulation.†

Why does the urine accumulate in the bladder? why does it not immediately pass out by the urethra, or flow back into the ureters? The answer, as respects the ureters, is very easy; these ducts pass for a considerable distance through the substance of the walls of the bladder. In proportion, therefore, as the urine distends this organ, it flattens the ureters, closing them most exactly when it is abundant. This effect takes place as well in the living as the dead body; a liquid, or even air, pushed with great force into the bladder, cannot be introduced into the ureters. It is owing, then, to a mechanism analogous to that of certain valves, that the urine does not return towards the kidney.

It is not so easy to explain the reason that the urine is not immediately poured into the *urethra;* many causes seem to concur in producing this effect. The walls of this canal, especially towards the bladder, tend continually to react upon themselves, and to efface its cavity. M. Amusat has demonstrated, by a series of very curious anatomical and physiological researches, that the membranous part of the urethra is formed externally by muscular fibres, and that these fibres are endowed with a very energetic contractility. I am satisfied of the accuracy of these facts. But the principal cause which prevents this effect is the contraction of the *levatores ani muscles*, which, either from the disposition in their fibres to shorten themselves, or from their contraction under the direct influence of the brain, press the urethra from below upward, thus bringing its walls in contact, and closing its posterior orifice.

* As it is proved that the heart and the elasticity of the arteries have a marked influence on the course of the blood in the capillaries and veins, may not these causes act upon the fluids in certain excretory ducts?

† Physiologists have often compared the introduction of the urine into the bladder to that of a fluid into a cavity with resisting walls, by a narrow, vertical, and inflexible canal; but the comparison is not exact. In the supposed canal, the fluid runs and presses continually the fluid contained in the vessel which receives it. The urine does not run in the ureter; it trickles, drop by drop, and in this respect its influence upon the distention of the bladder cannot be compared to that which is produced by the weight of a fluid. The abdominal pressure must have a great influence in the dilatation of the bladder by the urine. If the bladder and ureters be equally pressd, this cause will be sufficient to introduce the urine into the bladder. Supposing the pressure to be equal in every part of the abdomen, if the surface of the pelvis of the kidney and ureters be superior to the bladder, the urine should enter easily into the last. But the abdominal pressure appears to be much weaker in the cavity of the pelvis than in the abdomen, properly so called. It is thus easy to conceive how the urine passes from the ureters into the bladder. However, the distention of the bladder by the urine has its limits. When it is carried to such an extent that the organ contains more than a pound of urine, the distention stops, and the ureters, in their turn, become dilated from their inferior towards their superior part.

Excretion of the Urine.

When the urine is accumulated in certain quantities in the bladder, we feel a desire to expel it. The mechanism by which this is effected deserves particular attention, as it has not been always rightly understood. If the urine be not constantly passing out, this is not owing to any want of contraction in the bladder, for this organ has always a tendency to react upon itself. But, by the influence of causes that we shall now point out, the internal orifice of the urethra resists this with a force that the contraction of the bladder is incapable of overcoming. This condition of things is removed by the will; first, by adding to the contraction of the bladder that of the abdominal muscles; second, by relaxing the elevator muscles of the anus, which close the urethra. When this resistance is once overcome, the contraction of the bladder is sufficient for the complete expulsion of the urine which it contains; but if the action of the abdominal muscles be added, the force and size of the stream is much increased. We can suddenly stop the flowing of the urine by contracting the levatores ani muscles.

The contraction of the bladder is not voluntary, though, by the action of the abdominal and levatores ani muscles, we can permit its contraction at pleasure. This contraction is sufficient to expel the urine; I have often seen dogs urinate after the abdomen was opened, and the bladder no longer exposed to the action of the abdominal muscles. If we detach the bladder with the prostate, together with a small part of the membranous portion of the urethra, in a male dog, in a few minutes the bladder will contract, and the urine be thrown out with a jet to a considerable distance, until entirely expelled. What urine remains in the urethra after the bladder is emptied is expelled by the contraction of the muscles called the *acceleratores urinæ.*

Though the quantity of this fluid is very abundant, and though it contains many immediate principles not found in the blood, and which are, therefore, formed by some chemical action in the kidneys, the secretion of urine is very rapid. During health the urine is of a yellow colour, more or less deep, its taste saltish, and a little acid, and its odour peculiar. It is composed of water, mucus, probably derived from the mucous membrane of the urinary passages, of other animal substance, uric acid, phosphoric acid, lactic acid, muriate of soda and ammonia, phosphate of soda and ammonia, lime, magnesia, sulphate of potash, lactate of ammonia, and silex. The physical properties of the urine are subject to great variations. If we make use of rhubarb or madder, it becomes of a deep yellow; if we respire air loaded with the vapours arising from turpentine, or if we take this drug internally, the urine assumes an odour like violets; every one knows the disagreeable odour of the urine after eating asparagus.

Its chemical composition is equally variable. The more water we drink, the greater the proportion of water in the urine; and the

reverse. The uric acid becomes abundant when the diet is very generous, while the person exercises but little; but this acid diminishes, and may even be made to disappear entirely, by the continued and exclusive use of non-azotic aliments, such as sugar, gum, and butter, &c. Some salts, when introduced into the stomach, even in small quantity, are found in a very short time in the urine. The extreme rapidity with which this is effected has given rise to the belief that there exists a direct communication from the stomach to the bladder; even at this time there are many persons of this opinion. For a still longer time it has been suspected that there was a duct passing from the stomach to the bladder; but no such part has ever been demonstrated. Some have thought, but without adducing any proof of the fact, that this took place through the cellular tissue, by the anastomoses of the lymphatic vessels.

Darwin having given to one of his friends a few grains of the nitrate of potash, collected the urine at the end of a few hours, and then bled him. The salt was found in the urine, but could not be recognised in the blood. Mr. Brande made a similar observation with the prussiate of potash; he concluded that the circulation is not the only medium of communication between the stomach and bladder, but did not undertake to explain what this medium was. Sir Everard Home is likewise of the same opinion. I have made some experiments with a wish to throw some light on this important question; and I have found, first, that when we inject the prussiate of potash into the veins, or into those parts where it will be rapidly absorbed, as the intestines or serous cavities, it soon passes into the bladder, where it may be recognised mixed with the urine; second, if the quantity injected be very great, its existence in the blood may be demonstrated by reagents; but if the quantity used be very small, it is impossible to detect its presence by any known method; third, the same thing takes place when we mix in a vessel the prussiate and blood; fourth, we can detect the existence of this salt in all proportions in the urine. There is nothing very remarkable, therefore, in the fact that Darwin and Brande could not find this substance in the blood, though its presence in the urine was distinctly perceived.

With respect to those organs which transport the fluids of the stomach and intestines into the circulating system, from what has been already said in speaking of the lacteal vessels and the absorption of the veins, it is evident that the veins absorb the fluids directly, and transport them to the liver and heart. The route which the fluids pass through, therefore, to arrive at the kidneys, is much shorter than is generally supposed; that is, through the lymphatic vessels, mesenteric glands, and thoracic duct.*

Experiment has given many results relative to the secretion

* Those who wish to see some very curious experiments on the secretion of urine, and particularly on the variations of the relations of the aqueous and solid parts of this fluid, will read with interest a work of Dr. Chaussat, a physician of Pisa, in the fifth volume of the *Journal de Physiologie*. These researches were continued for many years with a perseverance worthy of Sanctorius.

of urine that I ought not to pass over in silence. The removal of one of the kidneys of a dog is not followed necessarily by injury to its health. The most remarkable change is an increase in the quantity and promptitude with which the urine is secreted. If both be removed, death invariably follows in from two to five days. I have constantly observed, in these experiments, that the secretion of bile increases in an extraordinary proportion; the stomach and intestines become filled.

It was observed by Messrs. Prevost and Dumas, that after the extraction of both kidneys, a considerable quantity of urea was found in the blood. Thus it is shown that this substance is not formed by the kidneys, as has been generally supposed, they merely separating it from the blood, where it is formed. This fact was verified by Messrs. Vauquelin and Segalas. He farther remarked, that the introduction of urea into the blood excited the secretion of the urine, so that he regards the urea as an excellent diuretic.

In explaining glandular secretion, physiologists have given a loose rein to their imaginations. The glands have been successively considered as sieves, filters, and fermenting vats. Bordeu, and more recently Bichat, have attributed to their molecules a sensibility and peculiar motion, by which they elect from the blood which traverses them the particles proper to enter into the composition of the fluids they are destined to secrete.* Some have given to them atmospheres, departments; others have supposed them susceptible of erection, sleep, &c. But notwithstanding the efforts of many very eminent men, it must be acknowledged that we are at present entirely ignorant of what takes place in a gland when it acts. Chemical phenomena are necessarily developed. Many secreted fluids are acid while the blood is alkaline; many of them contain immediate principles which do not exist in the blood, and which are formed in the glands; but the particular mode of these combinations is unknown.

But we will not confound among these hypotheses of the action of the glands a very ingenious suggestion of Mr. Wollaston. This distinguished chemist, being under an impression that electricity, even when very weak, might have a decided influence upon the secretions, had recourse to the following curious experiment. He took a tube of glass about two inches high, and about three quarters of an inch in diameter, and closed one extremity with a piece of bladder. He then poured into the tube a little water with 1.240 part of its weight of muriate of soda; he then moistened the bladder, placed it upon a bit of silver, and bent a piece of zinc wire so that one of its extremities touched a piece of metal, and the other penetrated into the tube to the depth of about one inch. At this moment the external face of the bladder indicated the presence of pure soda. There was, therefore, from this very weak action of the electric fluid, a decomposition of the

* Bordeu acknowledges that this is a mere metaphorical mode of expression. *Vide* Researches on the Glands.

marine salt, and at the same moment the soda separated from the acid, and penetrated through the bladder. Mr. Wollaston thinks that it is not impossible that something analogous takes place in the secretions. It will be perceived that, before this idea can be fully admitted, many other proofs must be required.*

The discovery of M. Dutrochet of *endosmosis* and *exosmosis* may, no doubt, throw some light on the theory of secretion, but no decided result has been yet obtained; it has only furnished some conjectures of doubtful probability.

Many organs, such as the thyroid and thymus, the spleen, and the capsulæ renales, have been called glands by anatomists. Professor Chaussier has substituted for this denomination *glandiform ganglions.* We are totally ignorant of the uses of those parts, as they are, in general, most voluminous in the fœtus; it is thought that they perform some important function during this state, but there is no absolute proof of this. The works of physiologists contain a great number of hypotheses constructed for the purpose of explaining their functions.

General Doctrines of Secretion.

[When we recollect the vast variety of materials that compose the solids and fluids of the animal body; how essentially they differ from each other in their mechanical and chemical properties; the solids varying in density from a mineral to a mere jelly, the fluids from a bland halitus to the most virulent poison; and when we recollect that all these different substances are ultimately derived from a single fluid, the blood, we at once perceive the difficulties in which every inquiry must be involved which aspires to throw light on a subject so recondite and averse to all our knowledge and experience as these transformations. The various processes by which these alterations in the living body are effected have received the general denomination of *secretion*, by which is usually understood the operation of secerning or separating the newly-formed substance from the blood. But though our knowledge on this abstruse and mysterious subject is, in the nature of the case, loose and imperfect, yet so intimately are these secretory processes connected with every vital phenomenon, both in health and disease, that it becomes practically important to form as just ideas as possible on this subject.

The material from which all the solid and fluid parts of the body are ultimately derived is the blood; the instruments by which these transmutations appear to be effected are the nervous, vascular, and lymphatic systems and membranous structures, controlled by that unknown power, *life.* In our reasonings in the physical sciences, we refer all the changes which take place in matter to the simple or combined effects of three powers. These are mechanical agency, chemical attraction and repulsion, or one or both of these powers modified by the circumstance of life in organized bodies. The mechanical powers are

* For the secretion of the semen and milk, see Generation.

few, simple, and admit of great precision in their investigation. They refer to the forms and motions of considerable masses of matter, which thus come within the scope of our senses, and are, therefore, well understood. The chemical changes which take place in bodies appear to be dependant upon the influence which the atoms or minute particles of matter exert on each other at insensible distances. These operations are too minute to come within the scope of our senses, and are, therefore, chiefly judged of by their results. But by examining them in this way, modern chemists have attained a great degree of precision respecting the chemical changes which thus take place in the composition of bodies. It is perfectly demonstrable that the most extraordinary transformations take place, not only in the chemical properties, but the physical characters of bodies, in consequence of chemical attraction and decomposition. The same elements, chemically combined in different proportions, produce substances so widely different from each other in their appearance and qualities, that it seems scarcely credible that any such relation can exist. Take, for example, a few of the most common chemical elements, oxygen, hydrogen, nitrogen, and carbon, and recollect the great variety of different substances that may be produced by these chemical elements combined in different proportions; water, atmospheric air, nitrous oxide, nitric acid, hydrocyanic acid, &c., &c.

Many of the operations of living organized bodies are evidently referrible to mechanical and chemical laws similar to those that control dead matter.

When we examine the physical arrangements of the various organs and systems which compose the human body, we perceive their admirable adaptation to secure every mechanical advantage. The more we study and the better we comprehend the general objects and minute details, the more we are surprised at the exquisite skill with which these objects are accomplished. In the circulation of the blood, the numerous fragments into which the osseous system is broken up and each fitted to the other, and in the arrangement of the muscles, we recognise the most striking and beautiful illustrations of those hydraulic and mechanical principles which philosophy inculcates. We cannot examine the mechanism of the eye, as connected with our knowledge of the properties and laws of light, without something of the same sort of admiration we experience on viewing some exquisite production of art. There is such an obvious adaptation of the most simple and effective means to produce a given end, that we cannot doubt what objects the designer proposed to accomplish. Reasoning, then, from those things which are palpable and may be understood, to those which extend beyond the ken of our senses, we may legitimately infer that the same fitness exists between the structure and function of those parts which, from their minuteness, transcend our senses and comprehension. Thus, though we can perceive no relation between the mechanical structure of the muscles and their power of contraction, yet there can be no

reasonable doubt that such relation exists, and so of many other organs. But these mechanical arrangements are of no avail without the superaddition of that unknown power, *life*, by which these mechanical powers and laws are put in action and modified.

It is also obvious that many of the changes which take place in the living animal body are the results of chemical affinity and repulsion, modified by the same unknown, mysterious principle, *life*. The changes which take place in the external form and internal constitution of bodies, so that they acquire new properties, is believed to depend on certain attractions and repulsions which their elementary parts exert on each other. Now these changes are incessantly going on, both in living and dead bodies. But though the laws by which these changes take place in these two classes of bodies are analogous, they are not identical. Thus, all those substances appropriated to the support of the animal body, commonly called the *ingesta*, when once they have become absorbed into the system, come under a new series of chemical influences. Their elements still continue to attract and repel each other, thus forming new compounds, differing essentially in their properties; but the nature of these attractions, and, of course, the new substances thus formed, are essentially different from what is observed in dead matter. But when death takes place, then the elements which compose the animal body are again reduced to the same physical laws which govern other dead matter, and a necessary consequence is a decomposition into their original elements. Hence, in modern physical science, the expression *living chemistry* has been very appropriately introduced, referring to this manifest distinction.

One of the most remarkable circumstances in the economy of organized bodies, especially the more perfect animals, is the vast variety which their elements exhibit, both in their physical and chemical characters. The large surfaces are kept moistened, and in a state most suitable for performing their functions, by fluids exactly adapted to their circumstances. In the larger, close cavities, as those of the cranium, thorax, and abdomen, a thin *halitus* is constantly transuding from every point. The smaller, close cavities, as the joints, are kept lubricated by a fluid essentially different, and exactly adapted to their uses; while those cavities which communicate with the atmospheric air, are covered by fluids differing essentially from either. In health, these fluids are constantly deposited and taken away, and are not suffered to exist either in excessive or deficient quantity, so as to impede the function of the parts in which they are formed. There are, again, other new substances, formed for certain specific purposes, and which have certain apparatus expressly appropriated to their formation, as the chyme, the chyle, the saliva, the gastric and pancreatic juice, the bile, the semen, the milk, &c., while the solids themselves are undergoing a constant change and renovation.

Now when we recollect that these numerous solid and fluid substances differ from each other essentially in their physical and

chemical qualities, we naturally inquire, From what source are they derived, and how are they produced? Does our knowledge of the properties and laws of dead matter afford us any clew as to the modes by which the living body, by its own inherent power, accomplishes these extraordinary changes?

It cannot be pretended that there is, at the present day, any generally-received theory of secretion. To arrive at a correct view respecting the present state of our knowledge on this subject, it will be necessary to look back for a moment at those speculations which have occupied the greatest space in the confidence of the profession. Through the whole history of speculative medicine, we find one error uniformly prevailing. Physiologists, in all their attempted explanations of vital phenomena, have reasoned as if they must necessarily be the results of a single class of influences or agencies. Whatever has happened to be the favourite topic of the philosophy of the day, has been assumed as the only power to which these vital phenomena were referrible. Thus, the mechanical and chemical sects and the animists are the three classes of speculative opinions which have exerted the greatest sway in the profession.

The opinion was at one time almost universally received, that the secretions exist ready formed in the blood, and that they are separated from it by means of arteries of different sizes and forms, and going off at different angles from the main trunks. That the glands were mere filters, which only allowed their peculiar fluid to pass through. The effect of chemical agency was not admitted, but everything was referred to mechanical power. These were the opinions of Haller and others, who may be regarded as modern physiologists. But this hypothesis will not bear examination. In the first place, we find among the secretions substances which have no resemblance to the blood, and which it can be proved do not exist ready formed in the blood. For example, the bile differs as much in its chemical composition from the blood, or any of its known elements, as it does in colour, taste, and appearance. The same remarks hold good, in a greater or less degree, in all the secretions. They differ not only from the blood, taken as a whole, but the parts into which it spontaneously resolves itself, and also those into which it may be artificially divided. In a word, it is impossible to extract from the blood a substance exactly resembling even the most simple of the secretions, as the exhalations or serous transudations, as they are called. But it is not meant by this to deny that foreign substances are sometimes found in the blood. A free, oleagenous substance has been alleged to have been found in the blood in cholera and some other diseases; it has been said that the uric acid to exists in the blood of gouty persons, and that the formation of urinary and arthritic calculi may be prevented in these cases by avoiding aliments in which nitrogen abounds; while the presence of madder, indigo, &c., in the blood, appears to have been proved by chemical tests. Even the secretions have been occasionally observed preserving

some of their distinctive characters, and mixed mechanically with the blood; this has been particularly noticed with regard to the bile, the urine, and pus. The general belief, however, in these cases, is, that they have been absorbed after having been secreted by their appropriate organs. But even admitting, for the sake of argument, that all the secretions exist ready formed in the blood, and that they are separated by these small arteries and strainers; this does not get rid of the difficulty; it only throws it back, and keeps it out of sight. If we admit that all the secretions exist ready formed in the blood, the next question that arises is, Where does the blood get them? We are thus thrown into a new dilemma.

But though the exclusively mechanical doctrines of secretion have necessarily fallen before the progress of modern science, yet it has been more recently supposed that some of the secretions are formed by a mechanical operation, a mere filtering, while others undergo a chemical process. Thus, some are called *serous exhalations*, as the watery fluids formed on the surfaces of the serous membranes lining the close cavities, and in the cells of the cellular tissue; and others, resembling them, called the pulmonary and cuticular *transpiration*, thrown out from the surfaces of the lungs and the skin. These are considered by some physiologists as consisting of the more serous or watery parts of the blood exhaling or transpiring mechanically through openings in the textures; hence the name given to these fluids. At the same time, it has been perceived that the wax of the ear, the black pigment of the eye, the bile, &c., &c., which do not resemble any portion of the blood, require a much more elaborate process. The fluids called serous exhalations, and cuticular transpiration, resemble the serum of the blood. In very debilitated states, when the living fibre may be supposed to be in a very relaxed state, these fluids are often poured out in inordinate quantities. Thus, the serous exhalations are very apt to accumulate in the cellular tissue and close cavities in very enfeebled conditions, constituting dropsies; one of the most invariable symptoms which mark the close of chronic diseases is the copious cuticular transpiration commonly called colliquative sweats; while in those acute diseases where the energies are suddenly and effectively broken down, as in the collapsed state of cholera, and in the article of death from whatever cause, a cold sweat is poured out from the whole surface of the skin. All these phenomena seem at first satisfactorily explained by considering them a mere transudation of the serum of the blood, or leaking out between the interstices of the tissues or small openings in the capillary arteries, and, therefore, increasing with the relaxed state of the living fibre.

But there is great reason to doubt whether any of the fluids formed by the living body are produced by a mere mechanical process. It has been shown, by the nicest chemical analyses, that these exhalations and transpirations differ in their composition essentially from the serum. The cuticular and pulmonary trans-

piration are composed of the largest proportion of water, and the smallest of animal matter, of any of the secretions, except the aqueous and vitreous humours. It differs, however, from the serum, not only in containing much less animal matter, but also, according to Berzelius, in containing a free acid, *the lactic*, which is not found in the serum. Traces of iron were also found by Thenard in the pulmonary and cuticular transpiration, which do not exist in the serum. The fluids poured out by the serous membranes differ from the serum of the blood in containing a much smaller proportion of albumen. Thus these fluids, so essentially different from the serum, or any other part of the blood, in their physical characters and chemical composition, cannot manifestly be separated from that fluid by a mere mechanical arrangement, but are no doubt elaborated by distinct organs and peculiar processes. Still we are not authorized, from these facts, to infer that the mechanical arrangement does not constitute an essential circumstance in every secretory organ for the due performance of its functions. On the contrary, the moment the mechanical arrangement of the organ is disturbed, the process is proportionally rendered imperfect. This rule appears to hold true from the most minute and simple to the largest and most complicated organs. Thus, the derangement in the secretion of an organ is sufficient to raise a suspicion that a change has taken place in its mechanical structure. The accurate observations which have been made on this point is the foundation on which have been erected many of the most valuable improvements in the modern practice of physic. This has been most remarkable in the organs contained within the cavity of the chest; but every day is showing its applicability to the other organs.

The great difference in the forms, sizes, and general arrangements of the different secretory organs is sufficient to show that the mechanical form is an important circumstance. While some are small and simple, others are large and loose, and complicated. We cannot doubt that the greater size of the latter, and all this display of apparatus, are for some important end; nature is too economical in the expenditure of materials and power to use them unnecessarily. Compare, for example, the structure of the kidney with that of the testis. We can discover a manifest relation between the mechanical form of the former and its functions, it closely resembling a filtering machine. But when we trace in the testis the long, tortuous course of the blood-vessels, the infinitely delicate and complicated seminiferous tubes and excretory ducts, we can perceive no such relation, yet we cannot reasonably doubt that all this complex and delicate machinery is indispensable for elaborating this important fluid. The apparatus for forming the secretions is simple or complicated, large or small, supplied copiously or sparingly with blood, according to the nature of the secretion, the purposes for which it is supplied, and the quantity to be employed. We are, undoubtedly, quite ignorant of the ultimate structure of these organs, and can perceive no

more reason, *e. g.*, that the liver should secrete bile, or the mammæ milk, than the reverse. Nor is this surprising, for, after all, the structure of the glands does not appear to be much more incomprehensible to an enlightened mind than the apparatus of the chemist to one entirely ignorant of that science. If the minute parts of the glandular apparatus could be unfolded to our senses, no doubt we should perceive that the mechanical arrangements were indispensable in facilitating the combinations and elaborating the secretions. This remark probably holds good in all the structures of the body, though, from the imperfection of our organs of sense, we cannot discover these relations. We cannot perceive anything in the structure of the muscles which indicates a power of shortening themselves with force, nor in the eye of imparting the sense of vision. Still, there can be no reasonable doubt that these vital phenomena are, to a certain extent, dependant upon the ultimate mechanical arrangement of the organs. We can see in the relations which the muscles bear to the fixed and movable portions of the bones, that every mechanical advantage is secured for the purposes of locomotion, and that the obvious uses of the different parts of the eye are to delineate with great accuracy the pictures of objects which are presented to it upon the retina, though we cannot perceive any necessary relation between such pictures and the sense of vision. Still, we are justified in believing, from analogy, that such relation does exist. If our organs of sense were more acute or more numerous, so that we could appreciate other properties of matter, it is not improbable that we could clearly apprehend the fitness of the structure of the muscles to contract, and of the retina to produce the sensation of vision. The general inference, then, to be drawn from these views and reasonings is, that though secretion and other important vital phenomena cannot, for a moment, be supposed to be dependant exclusively on mechanical laws, yet that this is one of the indispensable circumstances connected with the production of these phenomena.

The attempt to explain secretion and other vital phenomena by purely chemical laws is equally inconclusive and unsatisfactory. The objection to this hypothesis is, that the living animal body is assumed to be a sort of miniature laboratory, with its tests and re-agents ready for use. Like the exclusively mechanical doctrines, it merely throws the question back, does not resolve it. How and where, we naturally inquire, are these re-agents formed, even admitting their existence, if they are not formed by secretion?

From the middle of the last century, when Dr. Franklin succeeded in demonstrating the identity of lightning and electricity, to the present day, the important influence exerted by this agent in the various operations of nature has become daily more obvious. Modern investigations have greatly extended our knowledge of the relations of this agent, especially under the forms of what have been called galvanic and magnetic electricity. Yet,

at present, we can scarcely be said to have done more than to have attained a glimpse of the magnitude of the subject. We have become acquainted with a number of facts which appear to indicate this as one of the essential agents concerned in the production of vital phenomena, especially secretion. Its power of producing muscular contraction, after the consciousness of the animal has ceased, has been long and familiarly known. The beautiful experiment of Dr. Wollaston, of decomposing the muriate of soda by means of a *very small galvanic battery*—one of the elements of the battery being a lady's silver thimble—has been alluded to. In a paper published by him in the Philosophical Magazine, in which he described this experiment, he advances the hypothesis that the nature of the secretions depends upon the electrical state of the glands. Finding the urine acid, he supposes that this must be in consequence of the highly positive electrical state of the kidneys; while the bile, being alkaline, he attributes to the negatively electrical state of the liver. A moment's reflection shows that these are mere gratuitous assumptions, resting on remote and loose analogies, notwithstanding the high authority of their author.

The experiments of Dr. Wilson Philip on digestion in rabbits appear to bear more directly on this point, viz., the influence of galvanic agency in secretion. He first proved, by a number of direct experiments, that the power of digestion in the rabbit is immediately lost on dividing the par vagum. He next endeavoured to show that the process of digestion could be kept up after the division of the nerve, by causing an electrical current to pass through the distal portion of the divided nerve. The experiments of Dr. Philip are curious and interesting, but by no means authorize the inferences he has drawn, viz., that nervous influence and galvanic agency are identical. This supposition is unsustained by his experiments, and in itself highly improbable.

The blood being the material from which all the secretions are formed, its electrical state has therefore been particularly examined, in the hope of throwing some light on this subject. A number of facts have been observed which go to show that the generation of animal heat is accompanied with certain electrical phenomena. Some facts of this kind are related by Humboldt and Berzelius, while Bellingeri asserts, from direct experiments, that the blood possesses a peculiar electricity, which it preserves independently of that of the atmosphere. He asserts as a result of direct observation, "That in gout, rheumatism, peripneumony, hydrothorax, intermittent fevers, phthisis, and syphilis, the blood has a different electrical state."*

But still a vast deal remains to be done before we can be justified in drawing positive conclusions concerning the influence of electricity in the production of vital phenomena. It is not improbable that many of the subtler processes of the animal body,

* *Vide* Dict. Méd. et Chir., t. xiv.

particularly secretion, digestion, the generation of animal heat, &c., will ultimately be found connected with electrical agency. But this, in the present state of our knowledge, is mere speculation.

But although we are ignorant of the precise mode in which many of these changes occur, yet there can be no reasonable doubt that true chemical decompositions and recompositions take place in the living animal body. Gelatine, for example, enters largely into the composition of certain parts of the body, especially in young animals. It abounds in the bones, tendons, especially the skin, which is almost entirely gelatine; yet, as has been already remarked, this material is not found in the blood; it must, therefore, be produced from the blood by a chemical process. The same observation applies to adipose matter, so abundant in some animals. A still more remarkable illustration of this is furnished by some of the mineral substances found in the animal body. The urea, and urinary and biliary calculi, are undoubtedly formed in this way. The quantity of mineral substances, particularly lime, alkalies, iron, sulphur, carbon, phosphorus, &c., both in a separate and combined state, appears to be much greater than is taken in by the food. This subject has been investigated by Vauquelin, Prout, Einhoff, Shrader, and Berzelius, who, after the most critical analyses, have arrived at some surprising results. Vauquelin, after the most careful observations on the composition of the egg-shells and excrement of fowls, and comparing them with the food, which was also carefully analyzed, concluded that a portion of the silex had disappeared, and new portions of lime formed. Dr. Prout made an elaborate series of experiments on the composition of egg-shells and the substances contained within, and compared these with the earthy and saline substances found in the chick after incubation. He appears to have been quite confounded at the results, and unequivocally asserts that the quantity of earthy matter found in the chick could not have existed in the soft parts of the recent egg. As we cannot, of course, admit the creation of new matter in such cases, the only explanation that can be given of these surprising results, if we acknowledge their accuracy, is, that the living animal body possesses powers of decomposition and recomposition which transcend those discovered by art, by means of which substances supposed to be elementary are thus decomposed and recomposed. This tends to confirm the speculations of some distinguished modern chemists, who have suspected that even the metals were compound bodies, of which hydrogen is one of the ingredients.

There is but one other mode of attempting to explain the phenomena of secretion, to which I shall briefly advert. It is that of the sect that has been called *animists*. They consider life as an independent existence, which controls all the functions of the body in a manner beyond our comprehension, and which it is therefore idle to attempt to explain. This was the doctrine of Stahl, and, to a certain extent, still prevails. It would appear that there are

two circumstances that have contributed to give currency and permanency to the views of the animists. The first is the numerous absurd speculations with which the profession has been inundated, through its whole history, concerning vital phenomena. Men of sober sense, at last, turned with disgust from such idle and puerile speculations, and were glad to take refuge in any supposition by which they were protected from them. Thus the animists came at last to receive with coldness and distrust every attempt to explain the phenomena of animal life, or absolutely to repel them with the vague reply, "that it was a vital action, and that we knew nothing about it." The second is a disposition to mingle certain theological dogmas with physiological doctrines. According to these views, the soul and the life are identical, and to undertake to ascribe the operations of the soul to physical causes is to incur the deep reproach of being a *materialist*, without it being precisely understood what is meant by that expression. It appears to be chiefly owing to these two causes that the doctrines of the animists have found, and still continue to find, many supporters, though involving as great absurdities as they aim at avoiding.

To assume that life produces all the changes observed to take place in the animal body, independently of physical causes and material agents, is contrary to reason and observation. That many of the phenomena exhibited by the living body are not understood, and that some transcend our senses and comprehension, is no doubt true. But it is equally certain that many others are fully within the sphere of our understanding: this doctrine is also objectionable from its tendency to discourage independence of thought and a proper spirit of inquiry.

From these premises the following conclusions respecting the process of secretion may be drawn:

1st. That this process is probably in no instance exclusively dependant upon mechanical agency; but that even the most simple of the secretions, as the exhalations and cutaneous transpiration, are newly-formed substances, differing essentially, in their chemical properties, from any part of the blood, and, therefore, produced by a peculiar process.

2d. That although secretion is in no instance a purely mechanical process, yet that the mechanical arrangement of every secretory organ constitutes an essential circumstance for the due performance of its office. Hence, in all instances where the secretory processes become morbid, we are led to suspect some derangement in the blood itself or in the mechanism of the secreting apparatus. In acute diseases, it is frequently slight, and easily restored; in chronic diseases, the perfection of the organization is often permanently injured, constituting what is technically called an organic disease, and is, therefore, incurable.

3d. That although, except in a very few instances, we cannot trace any relation between the mechanical form of the secretory organs and their functions, in consequence of the imperfection of

our senses, yet there can be no reasonable doubt but that such relation exists.

4th. It is probable that every secretion is formed by what is called a process of living chemistry, the mechanical arrangement of the secretory organ being one of the indispensable conditions, and adapted to facilitate the formation of the new substance, and to conduct it off when formed.

5th. That the precise agents employed by the living body in accomplishing these decompositions and recompositions are unknown, though obviously most potent. The experiments of Drs. Wollaston and Philip, and other facts, render it probable that galvanic agency is one of these powers, though its mode of operation is unknown, and even its employment for this purpose is by no means certain.

6th. That, though secretion is a vital process, and in many of its details transcends the power of our senses and comprehension, yet that in others it is within the scope of our understanding, and is a proper object of investigation.*]

OF NUTRITION.

We know that the blood supplies the materials for all the secretions, internal and external; that its powers are preserved by general absorption, and by the chyle and drink. It remains for us now to examine what takes place in the parenchyma of the organs and tissues during life; this is called nutrition. From the earliest periods of life to advanced old age, the body is constantly changing in weight and volume. The different organs and tissues present infinite varieties in consistence, colour, elasticity, and frequently chemical composition. The volume of organs augments when they are frequently in action; on the contrary, their dimensions diminish much when they remain long in a state of repose. By the influence of one or other of these causes, their physical and chemical properties exhibit surprising variations; a great number of diseases produce, often in a very short time, very remarkable changes in the conformation and structure of a great number of organs. If we mix madder with the food of an animal, during fifteen or twenty days, the bones present a red tint, which disappears when it is omitted.

There exists, then, in the very substance of the organs, an insensible motion of their particles which produces all these modifications. It is this intestine motion, of the nature of which we are ignorant, to which we give the name of *nutrition*. This phenomenon, which the observing spirit of the ancients did not allow them to overlook, has been the object of many ingenious suppositions that are admitted by some at this day. It is said, for example, that by means of nutrition, the whole body is renewed, so that at any given moment it is not formed of a single particle that composed it at some former period. Limits have even been assigned to this total renovation. Some have fixed three

* Editor.

years, others think it cannot be completed in less than seven; but there is nothing to justify these conjectures; on the contrary, some well-established facts appear to do away this idea.

Everybody knows that soldiers, sailors, and savages are in the habit of colouring their skin with certain substances, which they introduce into the tissue of this membrane. The figures thus traced preserve their form and colour during life, except under very peculiar circumstances. How does this phenomenon agree with this idea of renovation, which, according to authors, takes place in the skin?*

According to the supposition of which we have now spoken, it is understood, in the metaphorical language at present used in physiology, that the particles of organs cannot serve but a certain time in their composition; and, being no longer suitable to compose the organs, they are then absorbed, and replaced by new molecules arising from the aliment. It may be added, that the animal substances which compose our excretions are the *detritus* of the demolished organs, and that they are principally composed of particles no longer capable of serving in the composition of the body, &c.

Instead of discussing this hypothesis, let us examine the few facts which are ascertained on the subject of nutrition. In observing the promptitude with which the organs change their chemical and physical properties by disease and age, it appears that nutrition is more or less rapid, according to their particular tissue. The glands, muscles, skin, &c., change their volume, colour, and consistence with great rapidity; the tendons, fibrous membranes, the bones, and cartilages appear to have a much slower nutrition, as their physical properties change but slowly in consequence of age or disease.

If we take into consideration the quantity of aliments consumed in proportion to the weight of the body, it appears that the action of nutrition is much more rapid in infancy and youth than in the adult or advanced age; it is accelerated by the action of the organs, and retarded by their remaining in a state of rest. Children and young persons consume more food than adults and old persons; the last preserve their faculties with a very small quantity of aliment. All exertions of the body render a more abundant and nutritious diet necessary; a state of perfect repose, on the contrary, will permit a prolonged abstinence.

The blood appears to contain the greater part of the principles necessary to the nutrition of the organs; the fibrine, the albumen, the fat, salts, &c., which enter into the composition of the tissues, are found in the blood. They appear to be deposited in their parenchyma at the moment when the blood passes through them;

* The recent employment of the nitrate of silver, internally, in the treatment of epilepsy, has furnished a new phenomenon of this kind. After this remedy has been used for several months, the skin of many patients has become of a grayish-blue colour, probably owing to this salt being deposited in the tissue of this membrane, where it is placed in immediate contact with the air. Several individuals have remained in this state for many years, without the colour being diminished. In others, it has by degrees diminished, and disappeared at the end of two or three years.

the mode of this deposition is entirely unknown. There exists an evident connexion between the activity of the nutrition of an organ and the quantity of blood it receives. The tissues, the nutrition of which is rapid, have large arteries; when the action of an organ has determined an increased nutrition, the arteries and veins grow larger. There are many immediate principles entering into the composition of organs which are not found in the blood; such are uric acid, gelatine, &c. They are formed at the expense of the other principles in the parenchyma of the organs by a chemical action, the mode of which is unknown, but which is not less real, and must necessarily have an effect upon the development of heat and electricity.

Since the nature of the different tissues of the animal economy has been ascertained by chemical analysis, we know that they all contain a large portion of azote. Our aliments being, also, composed in part of this simple substance, it was probable that the azote of the organs was derived from them; but many respectable authors think that it arises from respiration, and others that it is entirely formed by the influence of life. Both these opinions are supported particularly by the example of herbivorous animals, which feed exclusively on substances not containing azote, or the history of certain nations, whose inhabitants live entirely on rice and maize; or that of negroes, who live for a long time upon sugar; and, finally, on what is said of caravans, who, in traversing the desert, have little other food for a long time than gum. If these facts prove, indeed, that men are capable of living for a long time without azotic aliments, it would seem necessary to acknowledge that the azote of the organs has some other origin than the aliments. But, in fact, nearly all the vegetables employed for the nutrition of man and animals contain more or less azote. For example, the raw sugar eaten by the negroes is composed of it in a considerable proportion; with respect to those people who are said to live on rice and maize, it is well known that they add to this diet milk and cheese; now cheese, of all the immediate nutritive principles, has the most azote.

It occurred to me that we might acquire more exact notions on this subject by submitting animals, for a sufficient period, to a particular diet, the chemical composition of which should be determinate and rigorously pursued. Dogs were very proper for these experiments, as, like man, they are nourished by vegetable and animal substances. Every one knows that a dog can live for a long time on bread alone; but from this fact nothing can be conclusively inferred relative to the production of azote in the animal economy, for the gluten contained in the bread abounds in azote. To obtain a satisfactory result, it would be necessary to feed one of these animals with a substance considered nutritious, but which does not contain azote.

With this intention, I put a dog, about three years old, fat and healthy, upon a diet exclusively of pure, refined sugar, with distilled water for drink; he had them both without any limit. For

seven or eight days he appeared to be very well; he was sprightly, ate with avidity, and drank as usual. He began to grow thin the second week, although his appetite was good, and he ate six or eight ounces of the sugar in twenty-four hours. His alvine excretions were neither frequent nor copious, and the urine was in sufficient abundance. The emaciation increased in the third week; the strength diminished, the animal lost its spirit, and its appetite became less. At this period there occurred, first upon one eye and then upon the other, a small ulcer on the centre of the transparent cornea; it augmented rapidly, and at the end of a few days it was about a line in diameter, its depth increasing in the same ratio; the cornea became soon perforated, and the humours of the eye discharged. This singular phenomenon was accompanied with an abundant secretion of the glands about the eyelids.

In the mean time the emaciation continued to increase, and the strength to diminish, and though the animal ate daily three or four ounces of sugar, its debility became so great that it could neither chew nor swallow; of course, every other motion was impracticable. It expired on the thirty-second day of the experiment. I examined the body with every possible precaution; there was no fat to be found; the muscles were reduced more than five sixths of their ordinary volume; the stomach and intestines were much diminished in size, and strongly contracted. The gall and urinary bladders were distended by the fluids peculiar to them. I requested M. Chevreul to examine them; he found them possessing nearly all the characters belonging to the urine and bile of herbivorous animals; that is, the urine, instead of being acid, like that of carnivorous animals, was sensibly alkaline, not exhibiting any trace of uric or phosphoric acid. The bile contained a considerable proportion of pycromel, a substance peculiar to the bile of the ox, and in general of all herbivorous animals. The excrements were also examined by M. Chevreul; they contained very little azote, though they ordinarily exhibit much of this substance.

Such a result deserved to be verified by new experiments; I was therefore induced to submit a second dog to the same regimen, namely, sugar and distilled water. The phenomena were similar to those just described, except that the eyes did not begin to ulcerate until the twenty-fifth day, and the animal died before the ulcer had penetrated into the cavity of the eye, as occurred in the dog that was the subject of the first experiment. In other respects, the same emaciation and debility, followed by death on the thirty-fourth day, occurred; and on opening the body, the same state of the muscles and abdominal viscera, especially the same characters in the excrements, bile, and urine, were discovered. A third experiment afforded exactly similar results; and I was therefore induced to conclude that sugar alone is incapable of nourishing dogs.

It was interesting to determine whether the defective nutritious qualities were peculiar to sugar, or whether they existed in common with other non-azotic substances, generally esteemed

nourishing. I took two dogs, young and vigorous, but small in size; I gave them for food very good olive oil and distilled water, as their constant diet. They appeared to be perfectly well for about fifteen days; after which they experienced a series of symptoms similar to those related of the animals that were fed on sugar. No ulceration of the cornea, however, took place, but they died on the thirty-sixth day of the experiment: they presented a similar state of the organs; and in the composition of the urine and bile, the same phenomena as in the preceding cases.

Gum is another substance which does not contain azote, but is generally considered nourishing; we might presume that it would act like sugar and oil, but it seemed desirable to determine this by direct experiment. With this view, I fed several dogs upon gum, and the phenomena I observed did not sensibly differ from those of which I have already given an account. I have recently repeated the experiment upon a dog with butter, an animal substance destitute of azote. Like the animals in the preceding cases, he at first supported this diet very well, but at the end of fifteen days he began to lose his flesh and strength. He died on the thirty-sixth day, although, until the thirty-second, I gave him this food as freely as he would eat it, and though he continued to eat until two days before his death. The right eye of this animal exhibited an ulcer of the cornea, similar to that mentioned to have taken place in the animals fed upon sugar. On opening the body, the same modifications of the bile and urine were noticed. Although the nature of the excretions of these animals showed that they had digested the substances which they had eaten, I was desirous of satisfying myself more positively on this point. For this purpose, after having fed several dogs upon oil, gum, or sugar, I opened them, and found that these substances were reduced into a particular chyme, and that they afterward furnished an abundant chyle. That which came from the oil was of a white, milky appearance; the chyle produced by the gum or sugar was transparent, and more watery than that of the oil. It is evident, therefore, that if these different substances do not nourish the body, it cannot be attributed to their not being digested.

Since the publication of these facts, in the first edition of this work, I have observed others not less important, which show how limited our knowledge still is on the subject of nutrition.

A dog was allowed to eat pure wheaten bread and drink common water at will. He died within fifty days, with all the signs of marasmus in the highest degree.

Another dog ate exclusively *military* or *munition* bread; his health continued perfectly good.

Rabbits or Guinea-pigs fed with a single substance, as wheat, barley, oats, cabbage, carrots, &c., will die, apparently from inanition, within a fortnight, and sometimes much sooner. But if the same substances be given together, or after short intervals, the animals live, and do well.

I fed an ass on dry rice, and afterward boiled it in water, be-

cause he refused the first; the animal lived only fifteen days. The last days he constantly refused to eat the rice. A cock was fed on boiled rice for several months, and preserved its health.

Dogs fed exclusively with cheese, and others with hard eggs, lived for a long time, but became weak and emaciated; lost their hair, showing imperfect nutrition.

The following is one of the most remarkable facts that have come under my observation. If an animal has lived for a certain time upon a substance which of itself cannot nourish it, as, for example, wheaten bread for forty days, it will be useless, after that time, to restore to it its ordinary diet and regimen. The animal will eat the new aliments with avidity; but it will continue to emaciate, and death will ensue with as much certainty and as soon as if the original exclusive diet had been continued.

The most general and important consequence deducible from these facts, and which ought to be followed up and examined, is, that diversity and multiplicity of aliments is a very important hygienic rule. This is indicated by our instincts, and the variations that the seasons bring in the nature and kind of aliments.

Messrs. Edwards and Balzac, in their interesting researches to decide the difficult question whether gelatine extracted from bones should be used as aliments by the poor classes, have arrived at results confirmatory of what has been said above.

Bread alone does not nourish dogs, as we have already remarked; but is this because it does not contain enough of the azotic principle? To remove this difficulty, authors have added to the bread pure gelatine of good quality. But this is not found sufficiently nourishing to support life. It is necessary to add to the mixture a small proportion of the sapid substance of meat (osmazome), that the nutritive process should be perfect.

The experiments made by me on the fifth pair of nerves have led to some singular results connected with the nutrition of the eye. If the trunk of this nerve be divided in the cranium, within twenty-four hours after the section the cornea becomes clouded, and a pearl-coloured spot formed. At the end of forty-eight hours, this part becomes completely opaque, the conjunctiva and iris inflamed. A turbid fluid is deposited in the anterior chamber of the eye, and false membranes cover the internal face of the iris; the crystalline and vitreous humour begin to lose their transparency, and in a few days it disappears entirely. Eight days after the section of the nerve, the cornea becomes detached from the sclerotica, and the humours of the eye, which remain liquid, escape by the opening. The organ diminishes in volume, becomes atrophied, and ultimately becomes a sort of tubercle filled with cheesy matter. Thus it appears that the nutrition of the eye is under the control of nervous influence. The same remark applies to the lachrymal gland, which receives special branches from the fifth pair, by the name of *lachrymal nerve*. This gland becomes atrophied and deteriorated, like the eye. Its functions, the secretion of tears, are abolished immediately after the section of the nerve distributed to it.

The action of the organs develops their nutrition; repose retards it, and complete inaction stops it in some. This will be proved by the following experiment. Place the eye of a pigeon in such a situation that it cannot act; at the end of fifteen days it will be in a complete state of atrophy. We see analogous effects in man. But generally a long time passes before atrophy of the optic nerve is apparent, and most frequently it is confined to the anterior part, at the decussation of the nerves.

A great number of tissues in the economy do not appear to undergo the process of nutrition, properly so called; for example, the epidermis, the nails, the hair, the teeth, the colouring matter of the skin, and perhaps the cartilages. These different parts are really secreted, either by particular organs, as the teeth and hair, or by parts which perform at the same time other functions, as the nails and epidermis. These parts seem to be formed to prevent the friction of foreign bodies, and are renewed proportionally; when completely removed, they are reproduced. It is a singular fact, that they continue to grow for several days after death; we have had occasion to mention a similar phenomenon respecting the mucus. Certain substances, particularly iodine, appear to have a marked influence upon nutrition. Their use accelerates or diminishes it; these opposite effects are obvious, and merit special attention. After these few observations on the principal phenomena of nutrition, it will be proper to examine a very important phenomenon, which appears to be intimately connected with nutrition and respiration; I refer to the production of heat in the human body.

OF ANIMAL HEAT.

A dead body, which does not change its state when placed in the midst of other bodies, soon acquires the same temperature, in consequence of the tendency of caloric to arrive at an equilibrium. The human body acts differently: when surrounded by bodies warmer than itself, it preserves, during life, a lower temperature; when surrounded by bodies of a lower temperature than itself, its temperature remains more elevated. There is, then, in the animal economy, two distinct and different properties; the one producing heat, and the other cold. Let us examine these two properties, and inquire, in the first place, how heat is produced. The principal, or, rather, the most evident cause, is respiration. Experiment demonstrates to us, in fact, that the blood becomes heated about one degree in passing through the lungs; and as it is carried from the lungs to every part of the body it carries everywhere warmth, and imparts it to the organs. We have already seen that the venous blood is a little colder than the arterial.

This development of heat in respiration appears to arise, as we have already observed, from the formation of carbonic acid, whether this takes place directly in the lungs or in the parenchyma of the organs. The very beautiful experiments of Lavoisier

and Laplace lead to this conclusion: they placed in a calorimeter animals, and compared the quantity of heat produced with the quantity of carbonic acid formed in a given time; within a very small proportion, the heat produced was such as would necessarily be evolved from the quantity of carbonic acid formed.

The experiments of Messrs. Brodie, Thillaye, and Legallois, also prove that, if the respiration of an animal be obstructed, either by placing it in a fatiguing posture, or in making it respire artificially, its temperature is diminished, and the quantity of carbonic acid formed less. In those diseases where the respiration is accelerated, the animal heat is augmented, except under particular circumstances. Respiration is, therefore, a centre from which the animal heat is developed.

Science has attained to considerable precision respecting the production of animal heat. M. Despretz has made numerous experiments on the comparison of the heat emitted by animals and the heat disengaged by the combustion that takes place in the substance of the lungs. It appears now to be well ascertained that four fifths of the heat in herbivorous animals is produced by respiration, and three fourths in carnivorous and birds.

The lungs, then, are the principal source of animal heat, as was indicated by the trials of Lavoisier and Laplace; but, in these essays, the comparison had not been made on the same animal. A Guinea-pig had furnished carbonic acid, and another animal of the same kind was used to measure the heat. It was necessary, therefore, to make numerous and precise experiments, so as to leave no uncertainty as to the office executed by the lungs in this important phenomenon. It was this which induced the Academy of Sciences to propose this as a prize question, for which M. Despretz was the successful competitor. We shall only refer to the physiological results of his work.

The following points appear to be established as results of these experiments:

1st. That respiration is the principal cause of the development of animal heat.

2d. That, besides the oxygen consumed in the formation of carbonic acid, a considerable quantity, in addition, at the same time disappears. It has been generally supposed that it is used in the combustion of hydrogen; but this explanation is not directly proved.

3d. That there is an exhalation of azote during the respiration of mammiferous, carnivorous, and frugivorous animals and birds; and, generally, that the quantity of azote exhaled is proportioned to the quantity of oxygen consumed in respiration.

In considering this as the source of heat in the animal body, we see that the caloric must be distributed unequally to the different parts of the body. Those parts which are most distant from the heart, or receive less blood, or which cool the easiest, must be generally colder than those which present a contrary arrangement. This, in fact, is found to be actually the case. The limbs are colder

than the trunk; they are often found at 88° or 90° Fah., and even less, while the cavity of the thorax approaches 104°. But the extremities have a considerable extent of surface in proportion to their mass; they are more distant from the heart, and receive less blood than most of the organs of the trunk. From the extent of their surface, and their distance from the heart, it is probable that the feet and hands would have a still lower temperature than what is observed generally, if these parts did not receive a large quantity of blood. The same disposition exists in all the external organs, the surfaces of which are very extensive, the nose, cartilages of the ears, &c.; their temperature is higher than would be anticipated from their surface and distance from the heart.

But, notwithstanding this foresight of nature, the parts with large surfaces lose their caloric more easily, and are not only habitually colder than the rest, but frequently experience considerable chills. The temperature of the hands and feet is frequently reduced, in winter, much below that of the neighbouring parts; this is the reason why we expose them the more freely to the fire. Among the means we instinctively use to prevent or remove the cold, are running, walking, leaping, &c., which accelerate the circulation; and blows and pressures upon the skin, which draw into the tissue of this membrane a large quantity of blood. Another method, equally efficacious, is diminishing the surface in contact with the body which conveys away the caloric, as flexion of the different extremities upon each other, or placing them in contact with the trunk. Children and weak persons often adopt this when they lie down;* for this, among other reasons, it is improper to dress children in swaddling clothes when they are to lie down in the cold. Our clothes preserve the heat; for the materials which compose them, being bad conductors of heat, do not allow it to escape from the body.

From what has been said, it appears that the combination of the oxygen of the air with the carbon of the blood is sufficient to explain most of the phenomena which occur in the production of animal heat; but there are some which, if real, cannot be explained in this way. It has been observed by persons worthy of belief, that, in certain local diseases, the temperature of the part diseased becomes higher than that of blood taken from the left auricle by several degrees. If it be so, the continual return of the arterial blood will not be sufficient to explain this increase of heat. The following researches were made by myself with a very delicate thermometer, and in no instance was the temperature of the inflamed part above that of the blood. In one instance the diseased hand was eight or ten degrees above that of the sound hand, but nevertheless it was below that of the blood. According to M. Despretz, under the most favourable circumstances, and then only in herbivorous animals, respiration furnishes not more than 89 per centum of the animal heat, while in carnivorous animals it

* See Memoir of Mr. Bies, in the Journal de Médicine, année 1817.

is not more than 80. Hence it is manifest that there are other sources of heat in the animal economy. They are probably connected with the processes of secretion, nutrition, and friction of the different parts on each other, which are modified in diseased parts. There is nothing forced in this supposition; for chemical combinations generally give rise to changes of temperature, and we cannot doubt that, both in secretion and nutrition, combinations of this kind take place in the textures of the organs.

By means of these two sources of heat, life may be preserved, though the body be exposed to a very low temperature, as that of winter in polar regions, where the thermometer often falls to 108° or 109° below zero. In general, we support with difficulty such excessive cold; and it often happens that those parts which are cooled the soonest freeze and mortify: this was experienced by many of the soldiers in the Russian war. However, as we are capable of resisting easily a low temperature, it is evident we possess the power of evolving heat to a great degree.

That of producing cold, or, in more precise terms, of resisting heat, is more limited. In tropical countries, it has often happened that men have died suddenly, apparently from the heat, when the thermometer has risen to 120° Fahr. But our power of resisting heat is by no means limited to this. Messrs. Banks, Blagden, and Fordyce exposed themselves to a temperature of nearly 257°, and found that their bodies preserved nearly their ordinary temperature. The more recent experiments of Berger and Delaroche have shown that the heat of the body could be raised by these means several degrees. It is not necessary, even for this effect, that the surrounding temperature should be very high. Having placed themselves in a stove at 119°, their temperature was raised about three degrees. M. Delaroche, having remained sixteen minutes in a dry stove, at 176°, found an increase of 4° in his person.

Franklin, to whom the physical and moral sciences are indebted for many important discoveries and ingenious observations, was the first who explained how the body resists excessive heat. He showed that this was the effect of the co-operation of the pulmonary and cutaneous transpiration, and that in this respect the bodies of animals resemble porous vases called *alcarrazas*. These vases, used in warm countries, allow the water they contain to ooze out, and thus to keep their surfaces constantly wet, from which arises a rapid evaporation, which cools the fluid they contain. To confirm this important fact, M. Delaroche placed animals in a warm atmosphere saturated with humidity, so that evaporation could not take place. These animals could not support but a moderate degree of heat, and became warmed as if they had no means of cooling themselves. It is thus placed beyond doubt that cutaneous and pulmonary evaporation are the causes by which man and animals resist a great degree of heat. This explanation is still more confirmed by the great loss of weight that the body undergoes when it is exposed to a high temperature.

From the facts which have thus been exposed, it is evident that the authors who have represented animal heat as fixed are very far from the truth. To judge correctly, it is necessary to take into consideration the temperature and humidity of the surrounding atmosphere. It is also necessary to consider the temperature of the different parts, and not to judge of one by that of another. Few observations have been made on the temperature peculiar to the human body; Messrs. Edwards and Gentil have most recently investigated the subject. These authors have remarked, that the place most favourable to judge of the heat of the body is the armpit. They have remarked a difference of nearly a degree between the heat of a young man and that of a young girl; the hand of the last presented a temperature somewhat less than 98°; that of the young man was nearly 99°. The same authors have observed remarkable differences in the heat of persons of different temperaments. There are diurnal variations; the temperature varies two or three degrees from morning to evening. In general, this subject requires farther investigation.

CHAPTER XIX.

FUNCTION OF GENERATION.

The functions of relation and nutrition are necessary to the existence of the individual; but, like all other animals, man is called on to exercise another very important function, the reproduction of his species. In its object, generation differs very essentially from the functions of relation and nutrition; but it differs still more essentially in this, that the organs which co-operate in it do not exist in the same individual; this constitutes the principal difference between the sexes.

Apparatus of Generation.

It is composed of the organs proper to man, and those peculiar to the female.

Organs of Generation in Man.

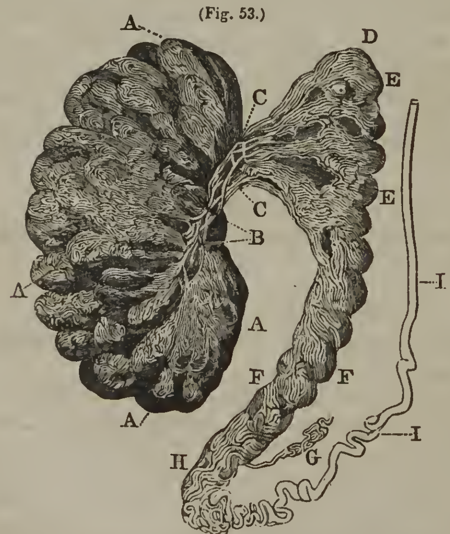
These organs are, the *testicles*, *vesiculæ seminales*, *prostate*, *glands of Cowper*, and *penis*.

The *testicles* are two in number; the cases related by authors who assert that they have seen three, and even four, are very doubtful. Their form is ovoid, and their size inconsiderable; their parenchyma consists of an infinite number of small vessels folded and rolled upon themselves, called *tubuli seminiferi*, and are directed towards a point of the surface called the *head of the epididymis.* Here they meet and anastomose, at the same time

diminishing in number, and finish by forming a convoluted canal called the *epididymis.* It soon leaves the organ, when it receives the name of *vas deferens.* It then rises up towards the inguinal ring, plunges into the pelvis, and arrives at last at the inferior and anterior part of the bladder; there it communicates with the vesiculæ seminales, and the *prostatic* portion of the urethra.

[The testis is evidently a glandular body, and in its tubular structure resembles the kidney. It consists of several lobules, which are separated from each other by processes of the tunica albuginea, that pass down between them, and also by an extremely delicate membrane (described by Sir Astley Cooper as the *tunica vasculosa*), consisting of minute ramifications of the spermatic vessels, united by cellular tissue. Each lobule is composed of a mass of convoluted *tubuli seminiferi,* throughout which blood-vessels are minutely distributed. The lobules differ greatly in size, some containing one, and others many tubuli. The total number of the lobules is estimated at about 450 in each testis, and that of the tubuli at 840. The convolutions of the tubuli are so arranged that each lobule forms a sort of cone, the apex of which is directed towards the rete testis. It is difficult to trace the free extremities of the seminiferous tubes, owing to the frequency of their anastomoses with each other. In this respect, therefore, the structure of the testis closely accords with that of the kidney. The diameter of the tubuli is very uniform in the natural condition, not exceeding from the $\frac{1}{170}$th to the $\frac{1}{195}$th part of an inch; but when injected with mercury, they are distended to nearly double that size. The following is a delineation of the human testis injected as completely as possible with mercury, after Louth. —(*Carpenter.*)

(Fig. 53.)

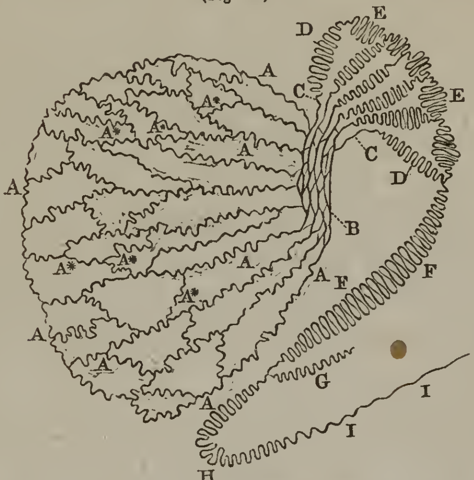


A A. Lobules formed by the seminiferous tubes. B. The

rete testis. C C. The *vasa efferentia.* D. Flexures of the efferent vessels passing to the head of the epididymis, marked E E. F F. The body of the epididymis. G. Appendix. H. The *cauda.* I. The *vas deferens.*

When the tubuli seminiferi have reached within a line or two of the *rete testis,* they are no longer convoluted; several are united together into tubes of a larger diameter, which enter the rete testis under the name of the *tubuli recti.* The rete testis consists of from seven to thirteen vessels which run in a waving course, anastomose with each other, and again divide. The accompanying figure is a plan of the structure of the testis and epididymis.

(Fig. 54.)



A A. The seminiferous tubes. A* A*. Their anastomoses. The other references as in the last figure.]

The parenchyma of the testicle is enveloped by a strong fibrous membrane; it is also covered, first, by a serous membrane called the *tunica vaginalis testis,* which in the fœtus makes a part of the peritoneum; second, by a muscular membrane which is capable of elevating the testicle, and applying it against the ring; third, by the *dartos,* a layer of loose cellular tissue, which appears to be contractile; fourth, by a rugous skin of a dark colour, which forms the scrotum, and possesses the property of contracting like the muscles, though not voluntarily.

The arterial blood arrives at the testicle by a small artery derived from the aorta, near the emulgent arteries. The veins of this organ are large, tortuous, and numerous; have frequent anastomoses, and have together received the name *pampiniform bodies.* Although the sensibility of the testicle is very great, it does not appear that any nerve can be traced to it either from the brain or ganglions.

The name vesiculæ seminales has been given to two small cellular bodies below the *basfond* of the bladder, and which appear

to be destined to contain the fluid secreted by the testicle. Their walls are thin, covered internally by a mucous membrane, and externally by a fibrous coat; we do not know whether the intermediate membrane is or is not contractile. The anterior extremity of these small vesicles communicates with the vas deferens and urethra by a very short and narrow canal called the *ejaculator*.

M. Amusat has ascertained, by a careful and delicate dissection, that the vesiculæ seminales are formed by a narrow duct of considerable length folded upon itself, and that its folds are held together by cellular tissue, like the spermatic ducts.

The penis is the only part of the male organs of generation which remains to be described. It is formed by the *cavernous bodies*, the *spongy portion of the urethra*, and the *glans penis*. The cavernous bodies principally determine the form and dimensions of the penis. They commence on the internal part of the *rami ischii*, approach each other, and soon unite to form the body of the penis. They are separated from each other by a fibrous partition pierced with several openings; their external membrane is fibrous, thick, hard, and very strong. Their interior consists of laminæ crossing each other in various directions, which together form a sort of sponge, in which the blood is extravasated. The urethra and glans, which are also essential parts of the penis, have a similar structure, but are not surrounded by a fibrous membrane. Six arteries are distributed to the penis; this part also receives many nervous filaments, arising from the nerves of the sacrum.

The genital organs in man really consist of but one apparatus of glandular secretion, of which the testicles are the glands, the vesiculæ seminales the reservoir, and the vas deferens and urethra the excretory duct. This secretion is indispensable for generation. We give the name of *semen* to the fluid secreted by the testicles. The small volume of these glands, the number and tenuity of the spermatic ducts, the small quantity of blood carried by the spermatic arteries, and the length and extreme narrowness of the vas deferens, render it probable that the quantity secreted is very small, and that it is propelled towards the vesiculæ seminales very slowly. It is probable, also, that the secretion is constant, but is increased by venereal excitement, the use of certain aliment, and the frequent indulgence of the venereal appetite. It is extremely difficult to explain how the semen is made to traverse the tubuli seminiferi, epididymis, and vas deferens. Perhaps it may be the effect of capillary attraction; an idea which appears to receive some support from the small size of these parts, and thickness and strength of their walls. It is somewhat easier to understand how the semen, having arrived at the extremity of the vas deferens, can penetrate into the vesiculæ seminales. The ejaculatory ducts embraced, together with the neck of the bladder, by the *levatores ani* muscles, will resist at first the fluid, which will find a more ready access to the vesiculæ seminales.

The semen, as it passes from the testicles, has never been an-

alyzed; the fluid which has been examined under this name is formed by the semen, the fluid secreted by the mucous membrane of the vesiculæ seminales, the prostate, and perhaps the glands of Cowper. At the moment when this fluid passes from the urethra it is composed of two substances, the one fluid, and the other thick and nearly opaque. When left to themselves, these substances mix, and the mass liquefies in a few minutes. The odour of the semen is strong and peculiar; its taste saltish, and even a little acrid. Professor Vauquelin, who analyzed it, found it composed of 900 parts of water, 60 of animal mucilage, 10 of soda, 30 of phosphate of lime. When examined by a microscope, there can be distinguished a multitude of small animalculæ, which appear to have a rounded head and a long tail. These singular beings move with a certain degree of rapidity; they appear to avoid the light, and to delight in the shade. To see them, it is only necessary to prick the testicle of an animal at an age when it is capable of fecundation, collect a portion of the fluid discharged, dilute it with warm water, and afterward place it in the focus of a microscope of moderate magnifying power. These animalculæ are only found in individuals capable of fecundation; mental depression causes them to disappear. M. Bory-Saint-Vincent sought for them unsuccessfully in two young and vigorous individuals who had suffered capital punishment, but found them in soldiers killed in battle; excesses have also been observed to cause their disappearance. They are only found in animals during the rutting season. Mules, though they have semen, are destitute of them.

[The semen is seen to be composed of three distinct elements: a fluid, granules, and animalcules; the latter are called *spermatozoa*. The *granules* of the semen are described by Wagner as round bodies, finely granulated on their surface. They must not be confounded with the particles of epithelium, which are sometimes mixed with the semen. The spermatozoa were first discovered by a student at Leyden named Horn, and first described by Leewenhoek. They present different forms in different classes, orders, genera, and species of animals. The figure on the following page is a representation, after Wagner, of the spermatozoa of the human subject, and their development.—(*Müller.*)

A. Represents the spermatozoa, consisting of a flattened head and a long, tapering, filiform tail; they are quite transparent.

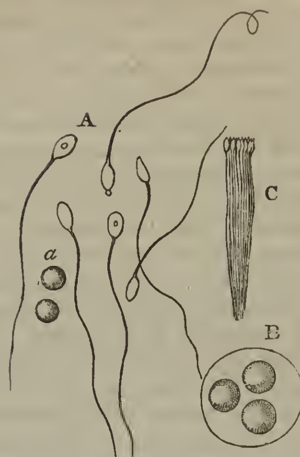
B. Are three granular tubercles, or seminal granules, from which the spermatozoa are developed.

C. Are the spermatozoa from the developed granules, lying side by side within the vesicle, which changes from a sphere to a long oval. After a time they break forth, but still adhere to each other for a short period, forming a bundle.]

The secretion of the semen commences at the age of puberty; before this period the testicles secrete a viscid, transparent fluid, which has never been analyzed, but which, to judge from appearance, differs essentially from semen. The revolution which the

(Fig. 55.)

Human Spermatozoa.



whole economy undergoes at this period, such as the tone of the voice, the development of hairs, the increase of the muscles and bones, &c., are intimately connected with the existence of the testicles and the secretion of this fluid; indeed, the removal of these organs previous to this period prevents this development from taking place. Eunuchs preserve the same form as in childhood; their larynx does not increase; their chin is not covered with hair; and their disposition is generally timid; and, finally, their physical and moral character very nearly resembles that of females. Nevertheless, many of them take delight in venereal intercourse, and give themselves up with ardour to a connexion which must always be unfruitful. In a state of health, before an emission of semen takes place, the spongy tissue of the penis becomes warm, hardened, and distended in every direction; in a word, in a state of *erection.* In this state, everything shows that the blood has been thrown into the penis in large quantity; its arteries are enlarged, and beat with more force; its veins are swelled, and its temperature sensibly augmented. These different phenomena are evidently under the influence of the nervous system.

Different explanations have been given of erection. It has been referred to the compression of the pubic veins by the muscles of the penis, and to the constriction of the veins by nervous influence, &c. But, as erection is an action purely vital, can it be explained? It may be produced by many and very different causes, such as mechanical excitement, venereal desires, the fulness of the vesiculæ seminales, the use of certain aliments, some medicines, and even certain poisons. It is also excited by several diseases, flagellation, &c. But, of all these causes, the imagination is by far the most prompt. One of the most remarkable phe-

nomena which attend erection is undoubtedly the great rapidity with which it is reproduced or ceases in certain cases. Generally, erection is attended with oozing of a viscid, transparent fluid, said to come from the prostate.

The circumstances which lead to the excretion of the semen, and the sensation which accompanies it, are sufficiently well known; but the mechanism of its evacuation is much less understood. Are the vesiculæ seminales emptied entirely, or in part, at the moment of emission? Is it their middle tunic which contracts itself, or are they all compressed by other forces? Do the muscular fasciculi which pass from the orifice of the ureters to the crest of the urethra concur in it?* Are the levatores ani relaxed at this instant? Is it the contact of the semen with the membranous or spongy parts which excites the sensation which accompanies its expulsion? &c., &c. We cannot give any positive answers to these questions.

Female Organs of Generation.

They are, the *ovaria, fallopian tubes, uterus,* and *vagina;* at least, these are the essential organs.

From the time of Stenon, the term ovaria has been applied to two small bodies, situated in the cavity of the pelvis, on each side of the uterus. Each ovarium is formed by an external fibrous membrane, and the interior by a peculiar cellular tissue; in the midst of which are fifteen or twenty vesicles, of which some are larger than others, and correspond, by one of their sides, to the external membrane, which is thinner in that part. These vesicles appear to contain the rudiments of the germ, and to bear the same relation to women that the eggs do to birds, reptiles, and fishes. They are formed by two membranous envelopes, and by a fluid which runs into a mass, and becomes hardened like albumen. When the ovaria are not developed, as sometimes happens in some individuals, it exerts an influence upon the economy analogous to emasculation upon the male. Steril women, for this reason, have sometimes a form resembling men; with hair upon the chin and about the mouth, and with a disposition and character like that of men. In such persons, the voice is often grave and sonorous, and the *clitoris* larger than natural. In this kind of imperfect woman (called a *Virago*) is often found inclinations in themselves immoral, and which are generally peculiar to man, which are interesting in a physiological point of view.

The fallopian tubes are two narrow canals, the one on the right, and the other on the left side of the uterus, which are media of communication between the internal part of the uterus and ovaria. Their external extremity is uneven and ragged; they are narrow through the whole of their extent. Their tissue, especially towards the uterus, is very analogous to the vas deferens.

In the cavity of the pelvis, between the bladder and rectum, is

* See Sir Charles Bell.

found the uterus; it is pyriform, and small in the ordinary state, but undergoes a surprising enlargement during pregnancy. We may divide it into *body* and *neck;* the last is embraced by the vagina; it has three orifices, two at the fundus of the uterus, communicating with the fallopian tubes, and one below, with the vagina. The tissue of the uterus is peculiar; there is nothing analogous to it in the animal economy, except some slight resemblance in the heart. Its structure is more easily studied in an advanced state of pregnancy than in the ordinary condition. There are two prolongations of this tissue sent to the inguinal rings, under the name of round ligaments, which spread themselves at the sides of the labia. A great part of the external surface of the uterus is covered by the peritoneum, which forms many remarkable folds about the organ. The internal surface is covered by a mucous membrane; when we examine this surface with a magnifying glass of considerable power, we can perceive a multitude of small openings: of which some, less numerous, but larger, belong to the veins of the organ; and others, more numerous, appear to belong to the capillary arteries. The arteries of the uterus are flexuous and large, in proportion to its volume; the veins are likewise numerous and large. They form in the substance of the tissue what has been improperly called by anatomists *uterine sinuses;* the nerves are less numerous, and come from the hypogastric plexus.

The cavity of the uterus communicates externally with the vagina, a membranous canal placed nearly vertically in the cavity of the pelvis. It is from six to seven inches long, and its size various, depending upon the circumstance of the individual having had children. Its internal surface, especially at the lower part, has numerous transverse folds, which allow the vagina to become stretched in pregnancy. At the inferior part of the vagina is the *hymen*, a delicate membrane, which nearly closes up the tube. The tissue of the vagina is composed of grayish fibres, crossing each other in various directions, somewhat analogous to those of the uterus. Below it is surrounded by numerous veins, which resemble the tissue of the cavernous bodies of the penis, and which form a *retiform plexus.* It is supposed that this part of the vagina is susceptible of erection. All the internal surface of this organ is covered with a membrane containing many mucous and sebaceous follicles.

The external female organs are the *labia* and *nymphæ*, folds in the skin, which are destined to become effaced during parturition, and the *clitoris*, which is a kind of small, imperforate penis, composed of two cavernous bodies, and of a sort of *glans*, covered with a *prepuce.* It is endued with great sensibility, and undergoes an erection similar to that of the penis.

Of Menstruation.

In most women, an aptitude for generation is indicated by a periodical sanguineous discharge, which takes place from the internal surface of the uterus, and is a true sanguineous exhalation. It

is called *menstruation*, because it returns regularly at the end of a month. There are, however, some women in whom this discharge recurs at the end of every fifteen days, others once in two months, others, again, in whom it has no fixed period, and some few cases in which it never appears. The approach of this discharge is indicated by particular signs, such as a sense of weight in the loins, lassitude in the limbs, and pricking and pain in the nipples. Its first appearance is sometimes marked by serious accidents; at others, the discharge suddenly takes place, without any previous indication.

The duration of the discharge, its mode, the quantity of blood exhaled, its colour and consistence, are equally variable. With some women the quantity of menstrual blood is considerable; sometimes to the extent of several pounds. When menstruation continues for eight or ten days, the discharge acquires all the qualities of arterial blood. In some individuals only a few drops of blood are discharged, which is frequently watery and destitute of fibrine; in others it has all the characters of venous blood; the evacuation continues hardly a day, or stops and returns again. During menstruation, the susceptibility of females is much increased; the least noise frightens, a slight contradiction affects them, and they are particularly irascible.

The regularity or irregularity of the return of the *courses*, the nature and quantity of the blood evacuated, and the duration of the evacuation, are intimately connected with the health of the individual; all deserve the particular attention of the physician. It has been shown, by the dissection of women who have died during menstruation, that the blood escaped from the internal surface of the uterus, the vessels of which were found red, and filled with blood, which readily ran into the cavity by slight pressure. Although the menstrual discharge takes place from the uterus, yet this is not always the case; many instances have been known where this evacuation occurred in the mucous membrane of the large intestines, stomach, lungs, and even the eye. Different parts of the skin have also been known to discharge blood periodically; thus, it has been known to issue monthly from one or more of the fingers, the cheek, the skin of the abdomen, &c.

Some distinguished authors, in their anxiety to find the immediate cause of menstruation, have attributed it to the influence of the moon, to the vertical position of the body, and to a generous diet. The period at which menstruation first takes place in this climate is towards the thirteenth or fourteenth year; it is earlier in warm, and later in cold climates. In equatorial regions, girls often arrive at puberty by the age of seven or eight years. Towards the age of fifty, but later in the northerly, and earlier in warm climates, menstruation ceases; and with it finishes the aptitude for generation. This period is called critical, and is sometimes marked by the development of alarming diseases. But it has been recently ascertained, from statistical facts by M. Benois, that this period of life, so far from being fatal to them, as was long

supposed, is more fatal to males. What we have said of menstruation is liable to many exceptions. Young girls have been often known to conceive before menstruation has taken place; old women, in whom the courses had ceased at the ordinary period, have had them reappear at the age of sixty or seventy, and have become mothers; lastly, women in whom menstruation has never been observed, have nevertheless become impregnated.

Copulation and Fecundation.

We have already remarked, that our individual existence is protected by certain instinctive sentiments. A sentiment of the same nature, but much more vivid and imperious, because its end is more important, secures the preservation of the species by inducing the sexes to approach each other for the purpose of coition. The part performed by man in the act of reproduction consists in depositing in the vagina, as near as possible to the os uteri, the semen. The part performed by the female is more obscure; a great number perceive, at this moment, the most vivid sensation of pleasure, while others appear insensible, and some even experience pain and disgust. Some discharge a large quantity of mucus at the instant when the pleasure is most exquisite, while in the greater number of females nothing of the kind is observed. In all these respects, there are not, perhaps, any two who resemble each other. These different phenomena take place in common copulations, *i. e.*, those which are not followed by fecundation.

We will now inquire what takes place in fecundation. We shall pass over in silence the ancient and modern systems of generation. Why should we overload the mind with these brilliant dreams, which have so seriously retarded the progress of science? According to the latest physiologists, the uterus absorbs the semen, and directs it to the ovaria, through the fallopian tubes, the ragged extremities of which embrace closely this organ. The contact of the semen causes the rupture of one of these vesicles, and the fluid which passes out, or the vesicle itself, is carried into the uterus, where the embryo becomes developed. However satisfactory this explanation may appear, we must take care how we too readily admit it; for it is purely hypothetical, and contrary even to the experiments of the most careful observers. In the numerous experiments made upon animals by Harvey, De Graaf, Valisnieri, &c., the semen could never be detected in the cavity of the uterus, much less in the fallopian tubes and ovaria. It is the same with the motion by which the fallopian tubes embrace the ovaria; it has never been shown by experiment. If we admit that the semen penetrates into the uterus at the moment of coition, which is not impossible, though it has never been observed, it will be then difficult to comprehend how the fluid can pass through the fallopian tubes to the ovaria. The uterus, when empty, is not contractile; the uterine orifices of the tubes are extremely small, and have no sensible motion.

From the difficulty of conceiving how the semen could be trans-

ported to the ovaria, some authors have imagined that it was not this substance that was carried to the ovaria, but only the vapour exhaled from it, which they called the *aura seminalis*. Others have thought that the semen was absorbed from the vagina, passed into the venous system, and arrived at the ovaria by the arteries.* The phenomena which accompany fecundation in women, then, are but little understood; an equal obscurity rests on the fecundation of the females of other mammiferous animals. With them, however, it will be much easier to conceive of the passage of the semen to the ovaria, inasmuch as the uterus and fallopian tubes are capable of a peristaltic motion similar to that of the intestines. Fecundation in fishes, reptiles, and birds, is effected by contact of the semen with the ovum; it may be presumed that nature employs the same mode with the mammalia. We may consider it, therefore, as highly probable, that the semen passes, either at the moment of coition, or some time afterward, to the ovarium, where it performs its specific action upon the vesicle, which is afterward to be developed.

But even if it be acknowledged that the semen finds its way to the vesicle of the ovarium, it still remains to be shown how its contact animates the germ. Now this is a phenomenon of which it is impossible that our senses should take cognizance. It is one of those mysteries which at present are, and will probably always remain, inexplicable.† But we have the experiments of Spallanzani on this subject, which have done as much towards removing the difficulty as perhaps can ever be effected. This illustrious naturalist has proved, by a great number of experiments, first, that three grains of semen dissolved in two pounds of water still preserved its fecundating power; second, that spermatic animalculæ are not necessary to fecundation, as several authors, particularly Buffon, supposed; third, that the seminal vapour has no fecundating property; fourth, that a bitch may be fecundated by injecting semen into the vagina with a syringe, &c., &c.

According to the experiments of Messrs. Prevost and Dumas, it would appear that the animalculæ are indispensable to fecundation; that they rise to the upper part of the uterus, but do not enter the fallopian tubes; that a very small grain or corpuscle, contained in the vesicle of the ovarium, passes out at the moment it is torn, that is, some days after coition; that this grain, described by De Graaf, descends through the fallopian tube, and meets the animalculæ, which fecundate it many days after the approach of the sexes. This *corpuscle* or *grain*, the existence of which is far from being demonstrated, has been the object of some curious researches by Dr. De Baer.

We must consider as conjectural what is said by authors of the general signs of fecundation. At the moment of conception,

* If there was any truth in this idea, a female might be fecundated by injecting the semen into the veins. This would be a curious experiment to try.

† The same obscurity surrounds this, as we find in the physical and moral resemblance observed between parents and children, the transmission of diseases, the sex of the new individual, &c.

it is said that the woman experiences a universal thrilling sensation, accompanied with a feeling of extreme pleasure, which continues for some time. The countenance becomes altered; the eyes lose their brilliancy; the pupil is dilated, and the face pale, &c. Without doubt, fecundation is often accompanied by these signs; but how many mothers are there who have never experienced them, and who have arrived at the third month of pregnancy without suspecting their situation? Our ideas of the changes which take place in the ovaria after fecundation are more exact. The most accurate observers have described a body of a yellowish colour, which is developed in the ovaria of fecundated females, which is at first rather large, but diminishes in size as pregnancy advances. But this phenomenon belongs to the history of gestation, which we are now about to investigate.

Of Pregnancy, or Gestation.

The period which elapses between fecundation and parturition is called *pregnancy*, or *gestation;* it is generally nine months, or two hundred and seventy days. All this time is required for the evolution of the organs of the new individual. To form precise notions of pregnancy, it is necessary to study successively the phenomena which take place in the ovaria after fecundation; those of the fallopian tubes, of the uterus and adjacent parts, those of the economy generally, and, finally, those which are peculiar to the fœtus.

Notwithstanding the numerous observations of anatomists and physiologists on the changes which take place in the ovaria after fecundation, we have still much to learn on this subject. The difficulty consists in knowing what is detached from the ovarium to pass into the uterus. Some assert that they have seen a small vesicle detached from the ovarium, and pass into the fallopian tube; while others maintain that nothing of the kind has ever been observed; but they allege that, a little after fecundation, one of the vesicles of the ovaria is ruptured, and that, with the liquid, there escapes a very small globular body, only visible with the microscope. This molecule, they say, will be the *ovum of the ovum;* or, in the figurative language so fashionable in Germany, *the ovum elevated to the second power.* I shall now proceed to give some of the results of my own observations on dogs, sheep, and rabbits, as connected with this difficult subject.

It is difficult to determine in these researches, whether the subject of the experiment has become fecundated. Nothing can be more uncertain than this; we may know, perhaps, that on such a day and hour the female suffered the approaches of the male; but it may have received them before or since; it is impossible always to watch over these details.

The animals most suitable for these investigations are undoubtedly the mare and the cow, the vesicles of which are almost as large as hens' eggs. But to make experiments upon these animals would require the resources of a rich agriculturist; and

even then all the great obstacles would not be removed. There would be still necessary an expertness, disinterestedness, and perseverance not often found in the scientific labours of the present day.

Twenty-four or thirty hours after a productive coition, those vesicles of the ovarium which are the most developed augment sensibly in volume. The tissue of the ovarium which surrounds them becomes more consistent, and changed to a grayish-yellow colour. In this state the tissue of the ovarium takes the name of *corpus luteum*, yellow body. The vesicle continues to grow larger until the second, third, or fourth day, and the corpus luteum grows in the same proportion; it contains a whitish opaque fluid, similar to milk in appearance. After this the vesicle ruptures the external tunic of the ovarium, and passes to its surface, where it adheres by one of its sides. I have seen, in bitches, vesicles thus pass out from the ovarium which had attained the volume of an ordinary hazelnut. In this state, they present no appearance internally that can be considered a germ; their surface is smooth, and the fluid they contain does not run into a mass as before fecundation.

After the escape of the *ovum*, the corpus luteum remains in the ovarium; it presents in its centre a cavity, which is large in proportion as it is near the period of conception; but in time it becomes diminished like the corpus luteum itself. This diminution, however, is very slow; and the ovaria always contain those of the preceding generation, which has frequently deceived observers. Thus, the first effects of fecundation take place in the ovaria, and consist in the development of one or more vesicles, and as many corpora lutea. Sometimes the vesicles are found filled with blood; they appear to have been too strongly affected by the semen. It appears, also, that, in certain cases, the vesicle of one or more of the corpora lutea become ruptured before their entire development; for it is not rare to find more corpora lutea in the ovarium than vesicles at its surface.

Action of the Fallopian Tubes.

Among the vesicles on the surface of the ovarium, there is ordinarily one which adheres to the open and mucous mouth of one of these tubes, the tissue of which is softened and gorged with blood, and exhibits a peristaltic motion. I have never directly detected the vesicle in the tube; but I have often seen the vesicle after it has descended towards the inferior part of the horn of the uterus, while another had contracted adhesions with the extremity of the tube. At this moment, the body of the tube was enlarged to nearly half an inch in diameter; it, of consequence, was sufficiently large to allow the vesicle to pass.

The period at which the vesicle traverses the tube appears to vary in different kinds of animals. In hares, it appears to take place on the third or fourth day; in dogs, the sixth or eight. It is probable that it is still later in women, and that it does not

take place until the eighth or tenth. Dr. Maygrier assured me that he had seen the product of fecundation thrown off by an abortion of the twelfth day; it was a small vesicle, slightly shaggy on its surface, and filled with a transparent fluid. The vascular appendices, in which the tubes terminate in the human subject, are probably intended to contract adhesions with the vesicle, after it is detached from the ovarium, and to pour upon it a fluid that favours its development. After the vesicle had passed, the tube contracts, and resumes its ordinary size. Having arrived at the uterus, the ovum unites itself intimately with the internal surface of this organ; it there receives the materials necessary to its growth, and acquires a considerable volume. The uterus accommodates itself to this change of form and volume, &c.

Alteration of the Uterus in Gestation.

During the first three months of pregnancy, the development of the uterus is inconsiderable, and is made in the cavity of the pelvis; but in the fourth it increases more rapidly, becoming too large to be contained in the pelvis, and rises into the hypogastric region. The organ continues to increase during the fifth, sixth, seventh, and eighth months; it occupies gradually a large space in the abdomen, compressing and displacing the neighbouring organs, crowding them into the hypochondriac and iliac regions. At the end of the eighth month it fills itself, the hypogastric and umbilical regions, and its fundus approaches the epigastric. After this the fundus sinks, and approaches the umbilicus. The neck of the uterus undergoes but little change in the first seven months of gestation; the viscus preserves during this time a conoid form. After this the length of the neck is diminished, and at last becomes nearly effaced, and the uterus assumes an ovoid form; its volume, according to Haller, is nearly twelve times larger than when empty.

It is impossible that the uterus should become altered so remarkably in its form, volume, and situation, without its relations to the neighbouring parts being essentially altered. In fact, the peritoneal coat, which forms the broad ligaments, is stretched, and the vagina elongated. The ovaria, retained by their arteries and veins, cannot rise with the fundus of the uterus; they are therefore applied to its side, together with the fallopian tubes. The round ligaments suffer its elevation as far as their length will permit; afterward they offer some resistance to it, which tends to carry the fundus of the uterus forward, which must have a favourable effect on the abdominal circulation, by diminishing the pressure on the large vessels. The abdominal walls undergo a considerable extension; hence the rugous appearance upon the abdomen of women who have borne children.

In proportion as the uterus develops itself, its tissue loses its consistence; it assumes a deep-red colour and a spongy texture; its structure becomes more distinctly fibrous. We see, externally, longitudinal fibres passing from the fundus towards the neck,

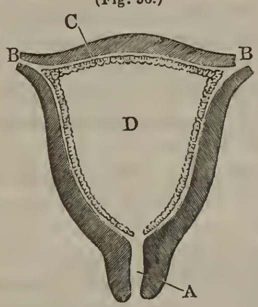
which are intersected at right angles by circular fibres. Beneath this tunic, the tissue of the uterus presents an inexplicable interlacement of fibres, in which no regular arrangement can be discovered. In this state, the organ appears to be endowed with a peculiar contractility, which, in animals, has a great analogy with the peristaltic motion of the intestines.

[But one of the most curious phenomena presented by the uterus occurs in its cavity after fecundation. As soon as the semen has produced upon the ovarium the important transformation of fecundation of the vesicle, the internal surface of the uterus becomes the seat of a secretion peculiar to that organ, and which appears to be indispensable to the ovum in the normal state.

A coagulable fluid, analogous to the albumen, is deposited, which forms a close sack, lining the inner surface of the walls of the uterus, and extending into the fallopian tubes. At first it is a viscid mass; afterward, by a sort of spontaneous organization, analogous to that of the lymph, it separates into two parts, the one solid, cellular, spongy, which adheres to the uterus, and the other liquid, which occupies the centre of a kind of sack formed by the solid part; it is called the *decidua vera.*

Below is a diagram of a section of the uterus with the decidua vera about eight days after impregnation, from Wagner.

(Fig. 56.)



A. The neck of the uterus.

B B. The entrances to the two fallopian tubes.

C. The fringe-like appearance covering the internal surface of the uterus and the entrances of the fallopian tubes, B B, but open at A, the neck of the uterus, is the *decidua vera.*

D. Is the cavity of the uterus.

This coat, which was first observed by William Hunter, and was called by him the *membrana caducea*, or *decidua*, remains during the whole process of gestation. M. Breschet gave to this the name of *perione*, and M. Velpeau *anhiste;* the first referring to its situation; the second, its structure. Of the two faces of this false membrane, the one adheres to the inner surface of the uterus; the inner surface, according to M. Velpeau, consists of a fine pellicle. The central liquid has never been analyzed; according to M. Velpeau, it is often reddish, and similar to the white of an

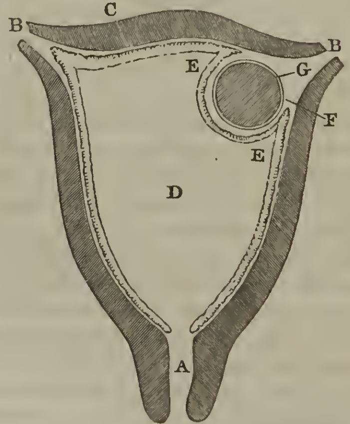
egg. According to M. Breschet, it is at first limpid, colourless, mucous, or slightly albuminous. This liquid at first is in small quantities, but increases with the development of the uterus, until it attains to several ounces. But as soon as the ovum acquires a certain development, its quantity diminishes gradually, and at last, when the ovum has become developed to a certain extent, it altogether disappears.

There is nothing yet known with certainty respecting the organization of this *intra-uterine false membrane.* M. Breschet regards it as endowed with organization and life, but adduces no satisfactory proof. M. Velpeau considers it a mere inorganic exhalation. We shall examine hereafter the curious office that this uterine production exercises on the first descent of the ovum into the uterus. Before this epoch, its use appears to be to close the orifices of the uterine cavity, and particularly to prevent the discharge of the liquid gradually deposited in the cavity of this new membrane. This central liquid appears to concur in the slow but regular dilatation of the cavity of the uterus, so as to prepare for the ovum a suitable place of deposite in the uterine cavity, and probably to furnish the first nutritive elements.

The changes which take place in the volume and structure of the uterus during gestation require modifications in the circulation. In fact, the arteries undergo a very considerable dilatation; the veins also become much enlarged, and form in the parenchyma what are very improperly called *uterine sinuses;* the lymphatic vessels also become very large. It is evident that the quantity of blood that traverses the uterus in a given time is proportioned to the changes it undergoes, and the new functions it is called upon to fulfil.

A diagram of the ovum after its entrance into the uterus, from Wagner.

(Fig. 57.)



F. Is the ovum, surrounded with its chorion, G. It has just entered the uterus through the fallopian tube, B, pushing the decidua

vera, E E, before it, to form the decidua reflexa, the name given to that portion of the membrana decidua which surrounds, and becomes, as it were, a part of the ovum after its entrance into the uterus.

A. The cervix uteri, or neck of the uterus.
B B. The fallopian tubes.
C. Points to the decidua vera.
D. The cavity of the uterus.]

General Phenomena of Pregnancy.

While all these phenomena occur in the uterus, important modifications take place in the functions of the mother, and commence often immediately after fecundation. Menstruation does not reappear; the mammæ swell, and, if in a state of lactation, the milk becomes serous, and is frequently injurious to the infant. The eyelids are swelled, and of a bluish colour, and the countenance altered; the cutaneous transpiration assumes a peculiar odour; a general paleness, with a diminished or capricious appetite, are also often observed; sometimes continual nausea, with violent pain of the head, followed by distressing vomiting, occurs. The abdomen is often affected with an extreme sensibility, and at first becomes flattened; some females lose their sleep, and yet are unable to leave a recumbent posture without experiencing a sense of extreme fatigue; on the other hand, persons of a delicate constitution, and valetudinarians, often have their health very much improved; alarming diseases are sometimes arrested in the midst of their course, and do not again resume it until after parturition.

In general, the intellectual faculties of pregnant females are weakened, and they are affected to an unusual degree by the most trifling events; hence the necessity of those kindnesses and attentions which this peculiar situation demands. To these different symptoms, which it is impossible to explain, are added phenomena evidently arising from an augmentation of volume in the uterus, such as cramps in the limbs, swelling of the superficial veins of the thighs and legs, and a sensation of numbness or pricking, arising from an obstruction in the circulation. In the later period of pregnancy, the bladder and rectum being strongly compressed, the desire of passing urine and going to stool are frequent. We shall not add to these phenomena, the existence of which is certain, suppositions destitute of proof; for example, that fractures in pregnant women are attended with more difficulty than in other women, the contrary of which is shown by experience.

Arrival of the Ovum in the Uterus.

[In speaking of the action of the fallopian tube, we have said that there is nothing positively known as to the moment when the vesicle of the ovarium traverses this duct, nor the mode of progression; whether by a peristaltic contraction of the tube, the pressure of the abdominal walls, or by successive adhesions. The little ovoid body, however, arrives at the extremity of the

tube, where it meets the membrana decidua. But instead of becoming entangled in its cavity, as was believed by William Hunter, and since his time by many physiologists, the ovum glides between the decidua and the uterus, depressing the membrane slightly, or, according to M. Breschet, lodging in its substance.

The point at which it stops is variable, but the reason unknown; sometimes it stops in the vicinity of the tubal orifice; at others, descends to the lower part of the uterine cavity, even to its neck. It is easy to comprehend the utility of the decidua during the period of gestation. It supports the soft structure of the ovum, gently supporting it against the walls of the uterus, with which it forms a close adhesion.

The membrane which surrounds or covers the ovum immediately, called the decidua reflexa, in its structure resembles the decidua vera, though thinner. It becomes smooth on its outer surface, which is turned towards the decidua vera, and, like the inner aspect of the latter, is furnished with slight depressions. Towards the ovum the decidua reflexa is rough, and shaggy where it comes in contact with the outer surface of the chorion, with which it unites so intimately, that by the third they cannot be separated. At one part the ovum is not covered either by the decidua vera or reflexa, viz., the part where the placenta is formed. This indicates the point at which the reflexion takes place. In extra-uterine conceptions, the decidua vera is formed; but, as the ovum never enters the uterus, there is no decidua reflexa.]

Development of the Ovum in the Uterus.

At first the ovum is loose in the uterus; its volume is nearly as small as when it left the ovarium; but, in the course of the second month, its dimensions increase, and it is covered by long filaments of about a line in length, which ramify in the manner of sanguineous vessels, running into the membrana decidua. In the third month, we perceive them only on one side of the ovum, those on the other having nearly disappeared; but those which remain have acquired an increased size and consistence, and are implanted more deeply in the uterine wall. In the remainder of its surface the ovum presents only a soft, fleecy coat.

The little ovum, when at first it descends from the ovarium, only displaces a very limited portion of the decidua. But, as its volume increases, it detaches and pushes back from the uterine wall a greater extent of the membrane, which then covers one of its faces. The part thus detached projects into the central cavity, occupied, as we have seen, by a liquid, and this prominence is enlarged, and the cavity contracted, as the ovum increases. Thus a period at last arrives, about the third month of gestation, when the projecting ovum, covered with the decidua reflexa, meets the concavity of the membrane attached to the uterine walls, the decidua vera. It is unnecessary to add, that from this time, the central liquid of the original decidua vera disappears, inasmuch as the space that it occupied is now filled with the ovum it-

self. Former anatomists, particularly Dr. William Hunter, gave to this intra-uterine, membraniform body, the name of *decidua reflexa;* but they did not understand the true mechanism of its formation. Covering thus the ovum without containing it, the decidua has been compared to a serous membrane, but only as relates to its anatomical arrangement.

It does not appear that the two laminæ of the decidua vera and reflexa become ever united, as was long believed. At the full period of pregnancy it is still possible to distinguish them, though in intimate contact during the remainder of gestation. The ovum continues to increase and develop itself until the termination of pregnancy, when its volume equals that of the inside of the uterus; but its structure has experienced changes which we are now about to examine.

I do not know that any one has observed the human ovum at the moment of its passage through the fallopian tube. In the dog, a little after this instant, it was, as in the ovarium, smooth on the surface. It is not until it has remained for some time in the uterus that it becomes covered with asperities.

The smallest ova that have been examined in women were eight or ten days old, without the date being positive. They were of the size of a pea, their surface covered with filaments, imparting to them a villous appearance. Beneath this tissue was the ovum itself, formed of a membranous envelope, and interior liquid; we cannot, then, distinguish any trace of the germ, nor of the different parts, liquid, membranous, or vascular, which appear at a later period. There is not, then, any resemblance between this ovum and that of a bird, where we can easily observe, almost immediately after it has passed from the ovarium, independently of its membranes, a cicatrix, or first rudiment of the germ, and at least two liquids, which serve for the nutrition of the embryo, the yolk and albumen of the egg.

The villosities or flocculi which cover the human ovum have been the object of the special researches of Messrs. Breschet and Raspail. Each of its filaments is simple and fusiform at its point of insertion upon the ovum; it ramifies in such a manner that the trunk is forty times more slender than the summit. The summits of the ramifications form true spongioles, the physical properties of which are very suitable to contract adhesions, and exercise imbibition. Otherwise these filaments do not offer any anatomical arrangement which could lead one to suspect that they were destined, at a later period, to become blood-vessels; for they preserve their form and structure to the last period of gestation.

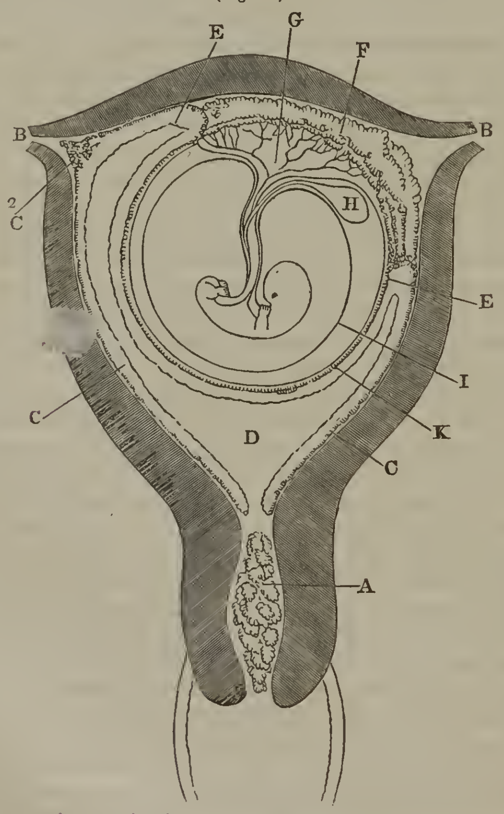
Having studied the alterations that the surface of the ovum undergoes, let us next examine those which take place in its structure. About the tenth or fifteenth day, dating from the period of fecundation, and from the fourth to the seventh, from the arrival of the ovum in the uterus, numerous and important modifications in its structure take place. Instead of one and the same interior liquid, we begin to distinguish many important parts and organs

necessary to the development of the ne[illegible] being. [illegible] parts are, 1st, the *amnios*, a thin and flexible m[illegible]brane [illegible] first rudiments of the *germ*, attached to a superfi[illegible]al p[illegible] [illegible] am-nios, under the form of a small opaque spot; [illegible] *ve[illegible] [illegible]a [illegible] il-icalis;* 4th, the *allantoides;* 5th, soon after ap[illegible]ars [illegible]e *um[illegible]i-cal cord,* which establishes a communication be[illegible]een the germ and the internal face of the chorion; 6th, the *om[illegible]hales-mesenter-ic vessels,* which connect the germ with the umbilical vesicle; 7th, and lastly, a prolongation of the allantoides, which unite, at a later period, the embryo and that membrane.

With respect to the liquids that appear at the same period, they are, 1st, the liquor amnii; 2d, that of the umbilical vesicle; 3d, the allantoidean liquid; 4th, a gelatinous mass about the c[illegible]rd.

[A sectional plan of the uterus, with the ovum farther developed, after Wagner. The placenta is seen attached to the fundus of the uterus, and the embryo suspended by the umbilical cord in the liquor amnii.

(Fig. 58.)



A. The cervix uteri, plugged up with a gelatinous mass.
The decidua vera sends a process, C^2, to fill up the right fallopian

tube. [illegible] he cavity of the uterus is almost completely occupied by [illegible] E. Is the point of reflexion of the decidua reflexa. G. [illegible] H. The umbilical vesicle, with its pedicle in [illegible] ca[illegible]rd. I. Is the amnion. K. The chorion; between the two [illegible]ter the space for the albumen.]

It is necess y to add to the whole of this special apparatus of the fecund ed germ, the numerous blood-vessels that adhere to the uterus, and which, under the name of the placenta, establish an indispensable communication between the circulation of the mother and that of the fœtus, in all the mammiferous animals.

Of the different organs or fluids of the ovum which we have enumerated, some remain to the end of pregnancy, and only leave the n w individual at the moment of its birth; others disappear early in gestation. The chorion, amnios, and its liquid, the umbilical cord and placenta, constitute the first. The liquid contained in the decidua, the umbilical vesicle, and the fluid it contains, the allantoides and its liquid, &c., constitute the second.

The Amnios.

This membrane is one of the envelopes peculiar to the fœtus. At the end of three weeks or a month, it forms a small sack of three or four lines in diameter, which contains the embryo, and the stem destined to form the umbilical cord, in the midst of a liquid.

According to M. Breschet, the germ is not contained even in the cavity of the amnios, and, consequently, is not plunged in its fluid until after fecundation. But, in the progress of this process, he states, that the germ buries itself towards the centre of the amnios vesicle, in the manner of the ovum in the decidua; so that, like it, there are two serous membranes which surround the embryo on all sides, though not contained in t' cavity. The germ, in burying itself in the amnios, or, rather, i. rusting before it that membrane, the latter forms a sort of sheath, in the midst of which is found the vesicula umbilicalis, &c.

The amnios does not touch immediately the concave or internal surface of the chorion; it is separated from it by a liquid of which I shall soon speak. That fœtal envelope grows with the principal product of the conception, and, at the moment of parturition, immediately covers it. As soon as the liquor amnii is drained off, it forms a sort of cap. Many anatomists have thought that, when the amnios reaches the umbilicus, it becomes continuous with the epidermis. But this is not proved, or, rather, the fact of that continuation, which appears to suppose a similitude of structure, is merely probable.

The amnios is not villous on either of its surfaces. The interval that separates it from the chorion, and its adhesions with that membrane, are ordinarily effaced towards the fourth month. The two membranous sacks are not then separated, except by a viscid coat, which continues to the end of gestation. Formed of a single sheet, the amnios does not present any blood-vessel in its composition. Its mode of appearance and growth is unknown.

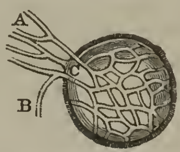
The amniotic fluid has been analyzed by many distinguished chemists, but at an advanced period of gestation. Vauquelin found it formed of water, albumen, soda, lime, and a particular acid. M. Berzelius asserts that it is fluoric acid. But its composition must vary at different periods of pregnancy.

Of the Vesicula Umbilicalis.

Towards the end of the second month of gestation, we find in the cavity of the chorion a distinct vesicle of the amnios. This is called the *vesicula umbilicalis.*

[Below is a magnified view of the umbilical vesicle, somewhat freed from other structures, after Baer.

(Fig. 59.)



A and B are portions of the omnion. Vessels are seen proceeding from these points towards the umbilical vesicle. C. The duct of the umbilical vesicle, returning to join the intestine.]—(*Wagner.*)

It is generally pear-shaped; its smallest extremity is turned towards the embryo, and is attached by a pedicle, which is confounded with the unformed organs of the abdomen. This pedicle is hollow; in birds, it transmits the yellow matter to the small intestine. In man, something of the kind occurs in the early periods of the embryo life, the umbilical vesicle at that time containing a yellowish viscid fluid, which, perhaps, has some analogy with the yolk of the egg in birds, reptiles, and fishes.

Sanguineous vessels, which pass from the mesenteric artery and vein, extend to the vesicle. The umbilical vesicle, at first almost as large as the amnios, diminishes in volume in the course of the second month, and disappears in the third, though it leaves traces of its existence much later. It represents, in the ovum of the mammiferi, the yolk of the egg in other vertebrated animals, and contributes, probably by the matter it encloses, which it pours out through its hollow pedicle, to the nutrition of the embryo at an early period of its existence.

Of the Allantoides.

In the ovum of birds and reptiles there exists about the amnios and vitellus a double membrane, which contains a particular fluid, and which is continuous, by means of a pedicle, with the cloaca, where the urinary canals terminate. In the ovum of the mammiferi, the same membrane exists; the fluid it contains varies in the different species; it communicates with the urinary bladder by means of a pedicle called the urachus. This membrane also exists in the human ovum, but its communication with the urachus

is very doubtful. Messrs. Breschet and Velpeau have sought for it in vain.

M. Velpeau, having dissected an ovum of three weeks, perfectly intact, found immediately below the chorion a very delicate coat, of a white colour; it was torn by a slight pressure upon another part of the ovum. This membrane was applied to the chorion by its external face, to which it was attached by numerous filaments. Beneath this first lamina there was seen a second, which enveloped the amnios, the umbilical vesicle, and its pedicle. Between these two laminæ was found a lamellated tissue, into which was extravasated an emulsiform substance, which escaped from the tissue in fleecy flocculi. This substance was not miscible with water. In other ova it was as transparent as the vitreous humour.

The two laminæ of this membrane are separated from each other three lines at one point, but approach each other as they go towards the root of the umbilical cord. It is this double membrane, this reticulated tissue, and the liquid that its meshes contain, that appear to form the allantoides of the human ovum. It is probable that the matter that it encloses concurs in the nutrition of the germ at an early period of the uterine life; but there is nothing positive known in this respect. In all cases, this sack, not having any known communication with the urachus, or, through it, with the bladder, cannot be, as in the mammiferi, the reservoir of the excreted urine.

M. Pokels, of Brunswick, thinks he has discovered in the human ovum another vesicle, which he names *erythoid;* but nothing has been sufficiently demonstrated on this point. M. Velpeau, who has dissected more than two hundred human ova, has never seen this vesicle.

Of the Germ.

We have already stated, that when the ovum arrives in the cavity of the uterus, we cannot observe any trace of the new individual, and that it differs in this essential point from the ovum of other vertebrated animals, where these traces are manifest as soon as the ovum is separated from the female. We have not, then, hourly and daily observations upon the development of the human ovum, as of those of birds. It is necessary not to content ourselves with suppositions, more or less probable, but to take facts observed with care and suitable instruments.

No precise observations have been made upon the human germ earlier than from the twelfth to the fifteenth day after fecundation. At this period the germ presents the form of a small, elongated mass, curved upon itself, and larger at one end than the other. With this appearance, a germ of from twelve to fifteen days is about two or three lines in length. Of its two extremities, one is swelled and irregularly spherical; the other terminates in a point, and has been taken for the tail, which some philosophical physiologists have supposed that man was originally

provided with. The whole trunk appears semi-transparent, hollow, and filled with a limpid fluid, the first index of the cephalo-rachidian liquid, in the midst of which we may see, even with the naked eye, an opaque filament, white or yellowish, which represents the cerebro-spinal system of nerves, or, in other words, the brain and medulla spinalis.

Numerous observations have proved, 1st, that the spine appears before the other organs, and exists alone for some time; 2d, that its form does not differ essentially from that which it presents during the whole uterine life; 3d, that the head and neck form at least one half its length; 4th, that the curvature is nearer to the circle in proportion as it is undeveloped; 5th, that its convex surface, corresponding to the posterior part of the trunk, differs little from what it will be in future, while its concavity, which corresponds to the abdomen and thorax, experiences very remarkable changes.

It is upon this surface that we see appear successively all the organs of nutrition, thoracic and abdominal, at the same time with the jaws and first indications of the extremities. The superior extremities pass out from the anterior part of the rachidian trunk at a nearly equal distance from the top of the head and the point of the coccyx. The inferior extremities are placed on a level with the pelvis, and, consequently, almost at the caudal extremity of the embryo. The head forms at first the most voluminous part of the germ, but as soon as the thorax and abdomen are formed, it loses its relative preponderance of volume. At six weeks, the face is distinct from the cranium. The eyes are visible, like black points, but without eyelids or lachrymal apparatus; they are directed laterally. The ears are at first indicated by a depression, afterward by the growth of the rudiments of the external ear. The mouth forms, at first, a very large opening; the upper jaw projects; the lower, on the contrary, is very short. The first rudiments of the nose are two small, black, flattened spots above the mouth. But at this time there is no nasal projection nor palatine arch.

However small the dimensions of the embryo, it is always attached by a funicular prolongation to the internal surface of the chorion, opposite to that part of the membrane attached to the uterus. This prolongation becomes soon the canal by which the new being will receive its nourishment. It terminates in the vascular tissue called the placenta, the embryo and fœtal organ of life, destined to establish indispensable relations between the mother and the new being.

It is not the object of this work to follow, step by step, the progress of development, organ after organ, tissue after tissue, after the period of conception. We must confine ourselves to the consideration of some of the principal functions of the fœtus, and particularly the circulation of the blood, which, at this period, differs much from its arrangements after birth.

By the end of about the fourth month, all the principal organs

have become successively developed. At this time the *embryo* state ceases, and the fœtal state begins, which continues until the end of pregnancy. During this time, all the parts increase, with more or less rapidity, and approach the state they exhibit at birth.

Before the sixth month, the lungs are very small; the heart is large, but its four cavities are confounded, at least difficult to distinguish; the liver is large, and occupies a great part of the abdomen; the gall-bladder is not full of bile, but of a colourless fluid, which is not bitter; at its lower part, the small intestines contain a yellowish matter, in small quantity, called the meconium; the testicles are placed on the sides of the superior lumbar vertebræ, and the ovaria occupy the same position. At the end of the seventh month, the lungs assume a reddish tint, which they had not before; the cavities of the heart become distinct; the liver preserves its large dimensions, but is a little above the umbilicus; the bile appears in the gall-bladder; the meconium is more abundant, and descends more into the large intestines; the ovaria approah the pelvis, and the testicles the inguinal rings. At this period, the fœtus becomes capable of breathing and living independently of the mother; it continues to grow more perfect until the eighth or ninth month, when it is expelled from the uterus.

We are ignorant of what takes place in the embryo while the organs are imperfectly formed; there is, however, a sort of circulation. The heart sends the blood into the large vessels and newly-formed placenta; and it is probable that the blood is returned to the heart by the veins, &c. But when the new being has arrived at the fœtal state, and the greater number of the organs have appeared, it is then possible to recognise some of the functions peculiar to this state. Of the different functions of the fœtus, the circulation is best understood. It is more complicated than in the adult, and is entirely different. In the first place, it would be impossible to make the division of the blood-vessels into arterial and venous, for the blood of the fœtus has everywhere the same appearance; it is of a brownish-red tint; in other respects it resembles the blood of the adult; it coagulates, separates into crassamentum and serum, &c. I do not know why some distinguished chemists have asserted that it does not contain fibrine.

The most singular, and the most important organ of the fœtus, is the *placenta;* it succeeds those filaments which, during the first month of gestation, cover the ovum. At first it is very small, but soon acquires considerable magnitude. By its external surface it adheres to the uterus, presenting irregular furrows, which divide it into several *lobes* or *cotyledons*, the number and form of which are not fixed; its fœtal surface is covered by the chorion and amnios, except at its centre, which gives insertion to the *umbilical cord.* Sanguineous vessels, divided and subdivided, form its parenchyma; they belong to the umbilical arteries and vein. The vessels of one lobe do not communicate with those of the neighbouring lobes, but those of the same cotyledon have frequent anas-

tomoses, and nothing is easier than to make injections pass from one to the other.

The umbilical cord extends from the centre of the placenta to the umbilicus of the infant; its length is often two feet; it is formed by the two umbilical arteries and the umbilical vein, united by a dense cellular tissue. It is covered by the two membranes of the ovum.

Having arisen at the placenta, and arrived at the umbilicus, the umbilical vein enters the abdomen, and passes into the lower surface of the liver; there it divides into two large branches, of which one is distributed to the liver with the vena portæ, and the other terminates suddenly in the vena cava, under the name of *ductus venosus.* This vein has two valves, the one at the place of its bifurcation, and the other at its junction with the vena cava. The heart and large vessels of the fœtus after the seventh month are very different from what they are after birth. The valve of the vena cava is very much developed; the partition of the auricles is perforated with a large opening, garnished with a valve, called the *foramen ovale.* The pulmonary artery, after having sent two small branches to the lungs, terminates in the aorta; it is called the *ductus arteriosus.*

Another character peculiar to the circulation of the fœtus is the existence of the umbilical arteries, which arise from the internal iliacs, run along the sides of the bladder, pass out from the abdomen through the umbilicus to the placenta, where they are distributed in the manner before described. From this arrangement of the circulating apparatus of the fœtus, it is evident that the course of the blood must be very different from that of the adult. If we suppose that the blood goes from the placenta, it is evident that it passes through the umbilical vein to the liver; there a part of the blood is directed to the liver, and another to the vena cava; these two routes lead to the heart by the vena cava inferior; having arrived at this organ, it penetrates into the right and left auricle, traversing the foramen ovale at the moment they are dilated. At this moment the blood of the vena cava inferior unavoidably mixes with that of the vena cava superior. Indeed, how could two fluids of nearly the same nature remain separate in a cavity where they arrive at the same time, and which contracts to expel them? I am not ignorant that Sabatier, in his beautiful Memoir on the Circulation of the Fœtus, has maintained a contrary opinion; but I confess his reasons have by no means altered my opinion in this respect.

The contraction of the auricles succeeds their dilatation, and the blood is forced into the ventricles; these, in their turn, contract and expel the blood, the left into the aorta, and the right into the pulmonary artery; but this artery terminates in the aorta, with the exception of a very small branch which goes to the lungs. Under the influence of these two agents of impulsion, the blood passes through all the divisions of the aorta, and returns to the heart by the venæ cavæ; but it is partly carried to the placenta by

the umbilical arteries, and returned by the vein. It is easy to conceive the utility of the foramen ovale and the ductus arteriosus. The left auricle receiving but little blood from the lungs, could not supply the ventricle if it did not receive it from the foramen ovale. On the other hand, the lungs not having any functions to perform, if all the blood of the pulmonary artery was sent to them, the action of the right ventricle would be lost; whereas, by means of the ductus arteriosus, the force of the two ventricles is employed to propel the blood in the aorta; without this action of both ventricles, it is probable that the blood could not arrive at the placenta, and return again to the heart.

The motions of the heart are very rapid in the fœtus; they generally exceed one hundred and twenty pulsations in a minute; the circulation is, of course, proportionally quick. A question now presents itself, which is extremely difficult, viz., What relation does the circulation of the mother bear to that of the fœtus? To arrive at anything like a satisfactory answer, it is, in the first place, necessary to examine the mode by which the placenta is united with the uterus. Anatomists have varied in opinion on this point. It was for a long time believed that the uterine arteries anastomosed directly with the branches of the umbilical veins, and that the last divisions of the placenta terminated in the veins of the uterus. But the impossibility of making injections pass from the umbilical vein into the uterine arteries, and *vice versa*, being demonstrated, this idea was abandoned. It is generally admitted now, that there does not exist any anastomosis between the sanguineous vessels of the placenta and those of the uterus. I have made some researches on this point, and the following are the results.

I at first repeated the attempts to inject the placenta from the uterine vessels, but without success; I even attempted this in living animals, without being more fortunate; I have used poisonous substances, the effects of which I was before acquainted with, odorous substances, &c., but I have seen nothing which has induced me to suspect that there is any direct communication. In bitches, towards the middle of gestation, a great number of small arteries may be distinguished, passing out from the tissue of the uterus, and dividing into numerous ramifications in the placenta. At this period, it is impossible to separate these two organs without tearing these small arteries, and producing considerable hemorrhage. But towards the end of gestation, in removing the placenta, however freely, these small vessels separate without the extravasation of blood. When we inject into the veins of a dog a certain quantity of camphor, the blood becomes of a strong camphorous odour. After having done this on a slut, in the latter period of gestation, I took a fœtus from the uterus; at the end of three or four minutes, its blood had not the odour of camphor. But that of a second fœtus, extracted after a quarter of an hour, had the odour of camphor very distinctly. The same was found to be the case with the other fœtuses.

Thus, notwithstanding there is no direct anastomosis between the vessels of the uterus and placenta, it cannot be doubted that the blood of the mother, or some of its parts, passes to the fœtus with a certain degree of promptitude. It is probably deposited by the uterine vessels on the surface, or in the tissue of the placenta, and absorbed by the extreme branches of the umbilical vein.

It is much more difficult to determine whether the blood of the fœtus returns to the mother. Among the small vessels which go in animals from the uterus to the placenta, we see nothing which has the appearance of a vein. In women, there are small openings, which communicate with the uterine veins, seen in that part of the uterus which adheres to the placenta. But we are ignorant whether these venous orifices are destined to absorb the blood of the fœtus, or to allow the blood of the mother to escape to the surface of the placenta; we may admit this last idea to be true, but there is no evidence of it. I have introduced into the vessels of the umbilical cord active poisons, directing them towards the placenta; but I have never seen the mother experience any effects, and even when she has died of hemorrhage, the vessels of the fœtus remained full of blood.

As no anastomosis with the vessels of the uterus exists, it is probable that the circulation of the mother has no other influence upon that of the fœtus than pouring blood into the areoles of the placenta. The heart of the fœtus is the principal moving power of its blood. It is, however, asserted that well-formed fœtuses have been born without any heart. But can these observations be depended on? There have been well-authenticated cases where the placenta was entirely separated from the dead fœtus, while it has continued to develope itself. M. Ribes recently observed a case where the umbilical cord was ruptured and perfectly cicatrized; how was the circulation carried on in this organ? We must conclude, therefore, that the relations between the circulation of the mother and that of the fœtus require new experiments.

Some authors have asserted that the placenta is to the fœtus what the lungs are to the adult; others have endeavoured to explain the large volume of the liver by attributing to it the same use. These assertions are entirely unsupported by proof. The functions of the capsulæ renales, thymus and thyroid glands, the dimensions of which in the fœtus are considerable, are also at present involved in impenetrable obscurity. This subject has often exercised the imaginations of physiologists, but without any real benefit to science.

Notwithstanding the imposing authority of Boerhaave, it is impossible to admit that the fœtus continually swallows the water of the amnios, digests it, and is nourished by it. Its stomach, it is true, contains a viscid matter in considerable quantity; but it resembles in no respect the *liquor amnii;* it is very acid and gelatinous; towards the *pylorus* it is grayish and opaque. It appears

that it is formed in the stomach; that it passes into the small intestines, where, after having undergone the action of the bile, and perhaps the pancreatic juice, it furnishes a particular chyle. The remainder descends towards the large intestines, where it forms the meconium, which is evidently the result of digestion carried on during gestation. Whence, it may be inquired, arises this digested matter? It appears probable that it is secreted by the stomach itself, or that it descends from the œsophagus; there is nothing, however, opposed to the idea that, in certain cases, the fœtus may swallow some mouthfuls of the liquor amnii; the fact that hairs similar to those of the skin are sometimes found in the meconium seems to prove this. It is important to remark, that the meconium is a substance that has little azote.

Nothing is at present known respecting the use of this digestion in the fœtus; it is not probable that it is essential to its development, inasmuch as it cannot exist in those instances where there is no stomach, nor anything which answers to it. Some persons assert that they have seen the chyle in the thoracic duct of the fœtus. I have never seen anything of the kind; in living animals, this canal and the lymphatics contain a fluid which appears to be analogous to the lymph, and which coagulates spontaneously like it. I have made some attempts to satisfy myself, by direct experiments, whether venous absorption took place in the fœtus in utero. I have injected into the pleura, peritoneum, and the cellular tissue, active poisonous substances; but I could not obtain any satisfactory result, as the nervous system of the fœtus, when it has not respired, appears to be insensible to the action of poisons. It appears certain that exhalations take place in the fœtus, as all its surfaces are lubricated nearly as they are afterward; the fat is abundant, and the humours of the eye exist. It is also probable that cutaneous transpiration takes place, and is continually mixed with the liquor amnii. With respect to this last fluid, it is difficult to say whence it is derived; no sanguineous vessels appear on the amnios; it is, nevertheless, probable that this membrane is its secretory organ.

The cutaneous and mucous follicles are developed, and appear to have a powerful action, especially after the seventh month; the skin is then covered by a thick coat of fatty matter, secreted by the follicles. Many authors have considered this as a deposition from the liquor amnii; the mucus is also very abundant in the last two months of gestation. All the glands which assist in digestion are of considerable size, and appear to have a certain degree of activity; we know but little of the others. We are ignorant, for example, whether the kidneys form urine, and whether this fluid is thrown out by the urethra into the cavity of the amnios. The testicles and mammæ appear to form a fluid, which does not resemble either semen or milk, which is found in the vesiculæ seminales and lactiferous ducts.

What, then, can we say of the nutrition of the fœtus? Physiological works contain only vague conjectures on this point. It

appears certain that the placenta receives from the mother the materials necessary to the development of the organs; but we are ignorant of the nature of those materials, and how they are obtained. Respiration not having taken place before birth, its heat cannot depend upon this. Experience has shown that it does not rise above 94° or 95° of Fahrenheit; it is said to be more elevated when the fœtus in utero is dead. If this be true, the fœtus must have a means of cooling itself which does not exist after birth. This is all we know of the nutritive functions of the fœtus; what relates to the functions of relation has been already explained.

As the mother transmits to the fœtus the materials necessary to its nutrition, it will be necessarily modified by the nature and quantity of the materials transmitted. If the quality be good, and the quantity sufficient, the growth will be natural; but if the proportion be small, or if the quantity be not proper, the fœtus will be badly nourished, and will either cease to be developed, or even perish. Now the moral condition of the mother must modify the nature and properties of these elements, which pass to the placenta; it is true, therefore, that her imagination has an influence upon the fœtus. It is thus that sudden terror, violent chagrin, or immoderate joy, may cause the death of the fœtus, or retard its growth. Physical causes, such as blows, falls, the action of certain medicinal agents, and the bad quality of the aliments, may have the same result, because they diminish or prevent the transmission of nutritive materials to the fœtus. If the mother be affected by a contagious disease, the fœtus will have symptoms of it; thus the life of the fœtus is in an evident state of dependance upon that of the mother.

Independently of the lesions which arise from this source, the fœtus is frequently attacked with severe diseases; such as dropsies, ulcers, fractures, gangrenes, cutaneous eruptions, the separation of one or more of the limbs, and many other internal diseases, both local and general. They often die of these diseases before birth; and if they are permitted to live until after birth, they are no longer capable of supporting life. The membranes of the ovum, placenta, and liquor amnii are also sometimes found in a morbid state.

In consequence of some unknown cause, the different parts of the fœtus sometimes develop themselves in a preternatural manner; so that one or more of the natural emunctories of the body do not exist, or are closed by membranes. Sometimes the lungs, stomach, bladder, kidneys, liver, and even brain, are entirely wanting, or are arranged in an unusual manner. In general, according to the remark of M. Beclard, when a nerve is wanting, the parts to which it should be distributed do not exist. According to M. Serres, the same remark applies to the artery. But this does not explain the phenomenon, as the question still remains, Whether the deficiency of the organ arises from the absence of the nerve or the artery? or whether the absence of the artery and nerve are not natural consequences of the defective organ? There

are other malformations or monstrosities, which depend on unknown causes, and seem to arise from a confusion of two germs, from which result children with two heads and one trunk, or two trunks and one head, or one trunk and four arms, or four legs well formed. There have been often found fœtuses not developed, in the bellies of individuals in advanced age. There is no reason for believing that the imagination of the mother can have any influence in the formation of these monsters; besides, productions of this kind are daily observed in the offsprings of other animals, and even in plants.

What has been called *Philosophical Anatomy!* of late, has seized upon the subject of *monstrosities*. It is found convenient and easy from its vagueness and obscurity. It pretends to nothing less than the creation of a new science, the theory of which reposes on certain laws not very intelligible, as that of *arresting*, that of *retarding*, that of *similar* or *eccentric* position, especially the *great law*, as it is called, *of self for self*.—(See *Traité de Tetratologie*, par M. J. Geoffroy-Saint-Hilaire.)

It is not very unusual for the uterus to contain two, instead of one fœtus. In France, this occurs as often as one in eighty; it appears to be more frequent in England. Three fœtuses in one gestation is much more rare; in thirty-six thousand labours in the "Hospice de la Maternité," in Paris, only four cases of this kind happened. There have been some well-authenticated instances where women have had four fœtuses in one gestation; but beyond this, the instances related by authors appear to be fabulous. In cases of plurality of children, the volume and weight of the children are in proportion to the number; twins are smaller than common children, &c., but whatever may be their size, they are each surrounded with a separate amnios and chorion, and have a distinct placenta. Their functions are separate, so that one may die while the others continue to become developed. There is nothing to countenance the belief, that in case of plurality of children, fecundation took place at two or three different times, and that there really exist instances of superfœtation. The histories of this which have been related are far from resting on the degree of evidence which is necessary in a science of facts.

Of Parturition.

At the end of the seventh month of gestation, the fœtus is in a condition to respire and exercise its digestive functions; it is then capable of an independent existence.* It is rare, however, that parturition takes place at this time; it generally occurs at the end of nine calendar months. There have been examples cited of the birth of children at the end of ten full months of gestation; but these cases are very doubtful, as it is so extremely difficult to determine the precise period of conception. According to the French Code, however, it is an established principle, that partu-

* There have been instances of birth at the end of the fifth month, where the child has lived.

rition may take place at the end of two hundred and ninety-nine days of gestation.

Nothing is more curious than the mechanism by which the fœtus is expelled; everything seems to have been foreseen and provided for with an admirable precision, so as to favour its passage through the pelvis and organs of generation. The physical causes by which this is effected are, the contraction of the uterus and abdominal muscles; through their agency, the membranes are ruptured, the water of the amnios discharged, the head of the fœtus forced into the pelvis, and passed through the *vulva*, the folds of which are effaced. These different phenomena take place in a regular succession, and are accompanied by pains, more or less severe, by swelling and relaxation of the soft parts about the pelvis and the external organs of generation, and an abundant mucous secretion in the cavity of the vagina. All these circumstances, each in its particular way, favour the passage of the fœtus. To facilitate the study of this complicated operation, it is necessary to divide it into several stages or periods.

First Stage of Parturition.—It consists of premonitory signs. Two or three days before parturition, an unusual discharge of mucus from the vagina is observed to take place; the genital organs are swollen, and become relaxed, and it is the same of the ligaments which unite the bones of the pelvis. The neck of the uterus becomes flattened, its opening enlarged, and its edges thinner; and slight pains, which are known in France under the name of *mouches*, or flea-bites, are noticed in the loins and belly.

Second Stage.—Pains of a different kind are soon developed; they appear to begin in the loins, are propagated either towards the fundus or neck of the uterus, and are renewed after considerable intervals, *e. g.*, a quarter or half an hour. Each is accompanied by an evident contraction of the body of the uterus, a manifest tension of its neck, and a dilatation of its mouth, or *os tincæ*. If the finger be now introduced into the vagina, we can distinguish the envelopes of the fœtus, projecting from the os tincæ. The contractions gradually become stronger, and the pains more severe, by which the membranes are at last ruptured, and the water discharged, when the action of the uterus is directly applied to the fœtus.

Third Stage.—The pains and contractions of the uterus now considerably increase, and are instinctively accompanied with contractions of the abdominal muscles. Women, perceiving their effect, are induced often to make all the muscular efforts that they are capable of. The pulse is also frequently increased, the countenance animated, and the whole body in extreme agitation, the sweat pouring from the surface in great abundance. The head being engaged in the pelvis, the occiput at first placed above the left acetabulum is carried inward and downward, and is passed beneath and behind the arch of the pubis.

Fourth Stage.—After some instants of repose, the expulsive efforts recommence; the head presents itself at the vulva, and en-

deavours to pass through, which is at last effected by a strong effort. When once the head is disengaged, the rest of the body soon follows. The umbilical cord is now tied, and divided, at a short distance from the navel.

Fifth Stage.—If the accoucheur does not immediately proceed to extract the placenta, in a short time slight pains are observed again; the uterus contracts feebly, but with sufficient force to expel the placenta and membranes; this has received the name of *deliverance.* During twelve or fifteen days, which succeed parturition, the uterus resumes gradually its original size and form, the woman perspires freely, and the mammæ become distended with milk. A discharge, at first bloody and afterward whitish, called the *lochia*, takes place from the vagina, which indicates that the organs are returning to their natural state.

As soon as it is separated from its mother, and sometimes before, the chest of the infant dilates, and the lungs are distended with air; and this motion continues to be repeated for the remainder of life. The lungs, being distended by air, permit the blood to pass through the pulmonary artery, so that the ductus arteriosus and foramen ovale, receiving less blood, contract gradually, and at last become obliterated. The same thing takes place in the umbilical vein and arteries, which are transformed into fibrous ligaments. The infant, at birth, is from eighteen to twenty inches in length, and weighs five or six pounds. In general, the number of male is greater than that of female children. The number of children that may be born of one mother cannot exceed the number of vesicles contained in the ovaria, that is, about forty.

Of Lactation.

The painful act that we have now described does not terminate the duties of the mother; the infant now requires care of a different kind; it must be protected against the weather; great attention is required for its preservation, and for its moral and physical education; lastly, nature has confided to her the power of furnishing its first aliment, and the only one suitable to the delicacy of its organs. This aliment is milk; it is secreted by the mammæ; the number, form, and situation of which are among the distinctive characters of the human species. Their parenchyma is entirely different from that of the other secretory organs. Each mamma has twelve or fifteen excretory ducts, which open at the top and sides of the mammary process, or nipple. The arteries which are distributed to the mammæ are small, but very numerous; they abound with lymphatic vessels and nerves, and are endued with a vivid sensibility. The mammary process, in particular, is very sensible, and is susceptible of a state analogous to erection.

Mammary Gland.

[Each mamma consists of a series of ducts, passing inward from the nipple, and ramifying like the roots of a tree, their ulti-

mate subdivisions terminating in minute cells. The ducts are twelve or fifteen in number, of variable size, and straight. Their orifices are situated in the centre of the nipple, and are usually concealed by the overlapping of its sides. At the base of the nipple, the tubes dilate into reservoirs, which extend beneath the areola and to some distance into the breast during lactation. They are much larger in many of the lower mammalia than the human subject. They supply the immediate wants of the child when first applied to the breast, before the secretion, or *draught, or flowing in of the milk*, as it is commonly called by nurses, takes place. From each of these reservoirs commence five or six main branches of the lactiferous tubes, each of which divides into smaller ones; these, again, divaricate until their size is very much reduced, and their extent greatly increased. The breast is not formed into regular lobes by the ramification of the ducts, because they ramify between, so as to destroy the simplicity and uniformity of their divisions.

The following is a representation, after Sir Astley Cooper, of the distribution of the milk ducts in the mamma of the human female during lactation; the ducts injected with wax.

(Fig. 60.)

The gland itself is composed of the union of a number of glandules, connected by the fibrous tissue; it is between these that the mammary tubes ramify. When the glandules are filled with injection, and long macerated and unravelled, they are found disposed in lobuli; when a branch of a mammary tube is separated with the glandules attached, it appears like a bunch of fruit hanging by the stalk. When the lactiferous tube is minutely injected, the glandules will be found composed of numerous cells, in which the ultimate ramifications of the tube terminate, or, more properly, originate. Their size, in full lactation, is that of a hole pricked in paper by the point of a very fine pin, so that the cellules, when distended with quicksilver or milk, are just visible to the naked eye.—(*Carpenter.*) The accompanying figure, showing the termination of a portion of milk ducts in cells, is from a mercurial injection of Sir Astley Cooper, magnified four times.

(Fig. 61.)

Termination of a Portion of the Milk Ducts in Cells.

The mammary gland in the male is a miniature of that of the female, varying in size from a pea to an inch, or even two, in diameter; it corresponds in structure with that of the female. In several well-authenticated instances, these organs have become fully developed, and the secretion of milk in considerable quantity established, as in the female during lactation.]

Until the period of fecundation, the mammæ remain inactive, not exercising any apparent secretion. But in the early periods of pregnancy, the woman observes peculiar pricking and darting pains, and the organs become swelled. After a certain period, especially as the end of gestation approaches, a serous fluid, sometimes in considerable quantity, is discharged from the nipple. The secretion often preserves the same characters for two or three days after delivery; but the milk, properly so called, does not appear until the end of that time.

The milk is one of the most azotic of the glandular fluids; its smell, colour, and taste are well known. According to M. Berzelius, it is composed of cream and milk, properly so called; the last contains 928.75 parts of water; 28.00 of caseous matter, with sugar; 35.00 of sugar of milk; 1.70 of muriate of potash; 0.25 of phosphate; 6.00 of the lactic acid; acetate of potash, and lactate of iron, 0.30. The cream contains, butter, 4.5; cheese, 3.5; whey, 92.0; or we find 4.4 of the sugar of milk and salt.

It has been long observed that the quantity and nature of the milk changes with the quantity and nature of the aliments; this has given rise to the singular opinion that the lymphatics were the vessels destined to carry to the mammæ the materials of their

secretion. But it is the same with the milk as it is with the urine, the properties of which vary with the solid or fluid substances introduced into the stomach. For example, the milk is more abundant, thicker, and less acid if the woman be nourished with animal substances; it is less abundant, thinner, and more acid if the diet be vegetable. The milk also assumes particular qualities if the woman has taken medical substances; it becomes purgative, for example, when rhubarb, jalap, &c., have been used. The secretion of milk is prolonged until the organs of mastication shall become sufficiently developed to prepare the aliment for digestion; it does not cease until the course of the second year; although the secretion of milk seems peculiar to parturient females, it has sometimes been observed in young virgins, and even men.*

OF SLEEP.

In terminating the history of the functions of relation, we remarked that these functions were periodically suspended; we also added that, during this suspension, the nutritive and generative functions were modified; and we are now about to examine these phenomena. After having been awake for sixteen or eighteen hours, we experience a general sensation of fatigue and weakness. Our motions become more difficult, our senses lose their activity, and the understanding itself becomes disturbed, perceiving sensations imperfectly, and commanding the contraction of the muscles with difficulty. From these signs, we perceive the necessity of giving ourselves up to sleep; we choose a position that requires no effort to preserve it, we seek darkness and silence, and then abandon ourselves to repose.

In sleep, we lose successively the use of our senses; vision is prevented by the eyelids being closed; smell ceases after taste, hearing after smell, and touch after hearing; the muscles of the extremities become relaxed, and cease to act before those of the head and spine. In proportion as these phenomena take place, respiration becomes slower and more profound; the circulation is retarded; more blood is carried to the head; the animal heat is diminished, and the secretions less abundant. However, when man is plunged into this state, he does not immediately lose a sense of his existence; he is still conscious of many of the changes which take place around him; a state which is not without its charms; ideas, more or less incoherent, succeed. At last he entirely ceases to be conscious of his existence; he is then asleep. During sleep, the circulation, respiration, and the different secretions remain slower; of consequence, digestion is effected with less promptitude. I do not know on what plausible ground many authors have asserted that absorption alone acquires new energy. As the nutritive functions continue in sleep, it is evident that the

* I have not thought proper to introduce into this work a particular description of the different ages, sexes, temperaments, zoological character of man, &c. These considerations properly belong to hygiene and natural history. See the article Hygiene, in the Encyclopédie Méthodique, and the new work of M. Cuvier, on the Animal Kingdom.

brain only ceases to act as the organ of intelligence and muscular contraction; but that it continues to influence the muscles of respiration, the heart, the arteries, the secretions, and nutrition.

Profound sleep exists when it is necessary to employ strong excitants to remove it; it is *light* when it ceases easily. Complete sleep is such as I have described; *i. e.*, it is the result of the suspension of the action of the organs of relation, and of the diminished action of the nutritive functions. But it is not rare that many of the organs of relation preserve their activity during sleep, as when we sleep standing. It may happen, also, that one or more of the senses remain awake, and transmit to the brain impressions which they receive; it is still more common for the brain to take cognizance of the different internal sensations which are developed during sleep, such as wants, desires, grief, &c. The understanding may exert itself during sleep either in an irregular and incoherent manner, or regularly and logically, as we meet with in some individuals.

We shall not, with some authors, seek after the proximate cause of sleep, and find it in a weakening of certain parts of the cerebellum, the afflux of the blood to the brain, &c. Sleep, being an immediate effect of the laws of organization, cannot depend on any physical cause of this kind. Its regular return is one of those circumstances which contribute most to the preservation of the health; when it is long prevented, it is often followed by serious inconveniences, and in no case can be carried beyond certain limits.

The duration of sleep is variable: in general, it is from six to eight hours; fatigue of the muscular system, great agitation of mind, numerous vivid sensations, indolent habits, the immoderate use of wine and substantial food, have a tendency to prolong it. In infancy and youth, the functions of relation being very active, more rest is required. Mature age, more avaricious of time, and surrounded by cares, requires much less. In old age, the two opposite extremes generally exist: either almost continual somnolency, or but very little disposition to sleep. By a quiet, uninterrupted sleep, restrained within due limits, the vital powers of the body are restored, and the organs resume their aptitude to act with facility. But if disagreeable dreams or painful impressions disturb our sleep, or if they are merely prolonged beyond a suitable limit, so far from restoring, it diminishes the forces, fatigues the organs, and becomes often a cause of serious diseases, such as idiotism and madness.

[Some few individuals are so happily constituted, that they can almost at will pass even from a state of great mental effort and excitement to deep sleep. This is alleged to have been the case with the two great military chieftains of the age, Bonaparte and Wellington, and, if true, must have constituted an essential element in their great achievements. It is, however, a rare gift.

Dreams.

When the individual is in health, and the sleep profound, the intellectual functions appear to be suspended, the individual losing for a time his consciousness, the mind slumbering like the body. But this is by no means universal; in some individuals, even in sound sleep, some of the intellectual faculties continue in a high degree of activity; this is especially the case with the imagination and memory. During dreams, the conceptions are sometimes striking, and the combinations of thought happy, and seem to surpass the waking powers of the individual. Thus, ingenious contrivances have been made, and the most delightful music composed, and individuals of education and taste, who have, perhaps, never written a verse, dream of reading poetry, the beauty and excellence of which their waking thoughts approve. At one moment we recall, with the most graphic accuracy, scenes and ideas long forgotten; in another, we are apparently forgetful of everything, even our own identity. Nothing can be more capricious and eccentric than the trains of thought which successively present themselves in our dreams. The present, the past, and an imaginary future roll before the mind in strange confusion; visions in which truth and error, the most brilliant and sublime conceptions combined with thoughts more wild and fantastical than could occur to one sane and awake, incessantly glide before it. It seems to afford a sort of living illustration of the possible independence of the mind upon the body; the individual appears to see without light, hear without sound, and to be transported without motion, by "most miraculous organs." It may be doubted if dreaming ever occurs in a perfectly normal state. There are reasons for considering this phenomenon as always indicative of a morbid condition, though often slight and transient. There is an obvious analogy between dreaming and delirium. In both the mental faculties are perverted, and in both the sensations and senses report falsely. It is certain that the dreams become more wild and impressive, and diminish the salutary effects of sleep as the health becomes more infirm. Excitement of the mind increases the disposition to dream, and renders the sleep disturbed and unrefreshing. If mental excitement be carried beyond a certain point, the power of sleep abandons the individual; and his waking thoughts at last become "such stuff as dreams are made of."

Incubus.

During sleep, the power of voluntary motion is, to a certain extent, suspended. In our dreams, we appear to transport ourselves through space with the speed of thought; yet we make not a muscular effort. Though we appear to ourselves to possess the power of voluntary motion as fully as when awake, and seem to talk and walk as usual, yet our volitions do not prompt our muscles to action. In the class of dreams called *incubus*, we are conscious of a loss of this power, and the sensation is most dis-

tressing. The patient experiences a sense of oppression about the præcordia, with embarrassed respiration, a consciousness of imminent danger, to which is superadded some frightful vision. He is incapable of the slightest power of voluntary motion or speech. He thinks, perhaps, that he is falling from a great height, or that he is standing on the verge of a precipice. He thinks, perhaps, that some movement is necessary to save himself from instant death. He struggles to accomplish it, or to cry out for aid; but his muscles refuse obedience to the mandates of the will. There is a temporary, but universal, paralysis of the muscles of animal life. It is remarkable, that while in this state, the slightest motion, often that of a finger, or a slight external excitement, as the voice of another, is sufficient to break the charm, and instantly restore the individual to his usual health. But in some cases, the impressions made by these dreams are such that it requires some time for the patient to rouse himself to a full consciousness of his situation, though awakened.

This variety of dreams, *incubus*, is one of the most common symptoms in many pathological conditions. In diseases of the heart and large vessels, and other chronic diseases of the chest, in which there is much dyspnœa and watchfulness, as asthma, hydrothorax, empyema, &c., chronic diseases of the liver, and in dyspepsia, especially after eating at night, it is a common and distressing symptom. It may arise from various causes; it is, perhaps, in most cases, more immediately connected with disordered functions of the stomach.

Somnambulism is another modification of dreams. It differs from common dreaming in this, that the individual retains, more or less perfectly, the power of voluntary motion, and actually executes during sleep what in other dreams is only imagined. Thus, individuals have been known to rise from their beds, go considerable distances, and in dangerous places, and return, yet in the morning be perfectly unconscious of what has happened. While the somnambulist is walking about, and even though the eyes be open, there is a want of speculation in their expression, and entire abstraction of the patient from surrounding objects and events, as in a common dream. They sometimes perform various acts which appear to imply vision, as walking in safety in perilous situations, writing, &c. Sometimes the eyes are shut, and they are heedless of surrounding objects, as in common sleep.

When this state occurs spontaneously, it is called *natural somnambulism.*

It is also alleged that a state of somnambulism may not only arise spontaneously in natural sleep, but, under certain circumstances, be artificially induced. The art of producing this state has been called, from its founder, *Mesmerism*, or *animal magnetism*. It has been alleged that certain gifted individuals, either with or without the magnet, and in consequence of some inherent mysterious power, can, at will, throw certain individuals into a state of somnambulism, and exert over them, while in this state, a

charm more potent than midnight witch, "with poppy or mandragora."

That a state of sleep or dreaming called artificial somnambulism may be induced in certain persons, appears to rest on strong proofs; but, at the same time, the subject is involved in great obscurity and difficulty from the superstitious excitement and self-delusion so common in this class of patients, and from its having been frequently combined with collusions and deliberate imposture.

The class of persons liable to this pathological condition are chiefly those of vivid imagination, excitable tempers, and delicate health, constituting what has been called persons of a nervous temperament. The patient, after having been subjected to certain ceremonies, begins to yawn, the eyes become heavy, and at last he appears to sink into a profound sleep. The temperature of the body is sometimes increased, and the pulse and respiration accelerated; at others it is the reverse, while occasionally no essential change takes place in either of these respects. There is often, during the paroxysm, twitching of the muscles of the face and a highly-excited state of the nervous system. The intellectual functions seem to be in a state analogous to that described as natural somnambulism. Though apparently the patient be asleep, and unconscious of everything passing around him, he may hold a continuous and coherent conversation. The memory, in some instances, has appeared to be remarkably developed, the person describing past events, quoting largely from books, and speaking in languages acquired in childhood, all of which was said to have been forgotten. Sometimes one or more of the senses have been stated to be suspended or remarkably modified. Thus, the loudest noises, as the report of a pistol, calling loudly, shaking, pinching, and pricking, and dashing cold water in the face, and, as has been recently alleged, even performing formidable surgical operations, have not appeared to excite the slightest emotion or wincing in the patient, yet a small current of air, blown with the mouth upon the skin, or the ticking of a watch, has seemed to annoy him. The sense of smell has in some instances appeared to be suspended, so that the most pungent odours, as strong ammonia, have been snuffed up without causing the slightest inconvenience.

The muscular power has been observed in some cases to be remarkably developed. Patients in this state have been known to leap to a great height over the furniture, upon the windows, &c., and to balance themselves in difficult postures. The patient may remain in a state of somnambulism for a longer or shorter time, after which he will awaken. It often appears difficult to rouse the patient from this state, as in ordinary sleep, by calling, shaking, &c.; yet, by flirting the hands for a few times before the face, or, as the magnetizers express it, by "renewing the passes," the paroxysm will pass off, the patient appearing like a person awaking from a deep sleep, and perfectly unconscious of all that

has passed. In some instances, patients have remained in a state of lethargy for hours; and in others, catalepsy, epilepsy, and convulsions have supervened. From what has been said, it will be perceived that there is much connected with this condition fitted to excite superstitious wonder, and offer ample scope for the ignorant and designing. Hence the many marvellous tales, and incredible, indeed impossible, things alleged respecting this class of patients; such as speaking languages they had never learned; describing accurately remote places and things of which they were ignorant; distinguishing the visual qualities of objects, not only with their eyes closed or covered with triple or quadruple bandages, but when applied to the back of the head. The power of performing these *miracles* with fantastical precision has been called *clairvoyance.*

When this pathological condition occurs spontaneously in the progress of sleep, it is obviously dependant upon idiosyncrasy. It is, for the most part, connected with some disease, as hysteria, indigestion, mental agitation, &c. Artificial somnambulism is induced by certain forms and ceremonies, during which the operator has been alleged to transfer to the patient a peculiar agent, called the magnetic fluid. The ceremonial consists in making what are technically called "passes," *i. e.*, passing the palms of the hands near the head, face, and along the sides of the patient; or by personal contact; pressing the lower extremities of the patient between those of the operator; placing the hands upon the head, grasping the thumbs &c.; or by merely looking intently or steadily at the patient. It has been even pretended that the magnetizer may transfer his power to other objects; *e. g.*, M. de Puysegur asserted that there was a certain tree in his garden, which he had so charged with animal magnetism, that persons, by looking at it, were thrown into a state of magnetic ecstasy. Does this explanation, given by professors of animal magnetism, satisfactorily explain the symptoms and causes of artificial somnambulism as described? Have we any evidence of the existence of a fluid possessing these remarkable properties? Is there sufficient evidence to warrant the belief that any individual possesses the power of transferring by volition such fluid? or is this state altogether a fiction? or, admitting its existence, can we satisfactorily explain the phenomena of artificial somnambulism by the known laws of the animal economy?

Though this subject has been so often combined with self-delusion, trick, and imposture, that it is almost impossible to draw the line between truth and error, and the facts must, more or less, rest upon the statements and actions of the patient, yet the occasional occurrence of such a condition rests upon testimony that cannot reasonably be altogether rejected. Admitting this, it would seem that this state is chiefly referrible to the influence of the imagination over the functions of the brain and nervous system, and, through them, the physical condition of the other organs.

We can scarcely fix a limit to the effects of the imagination.

Every intelligent physician is aware of its powerful influence, both in the production and cure of diseases. Thus, in fatal epidemics, we often see individuals protected from their effects, or rescued from the most perilous condition by their confidence in some unimportant medicine, or some rite, amulet, or charm, the whole efficacy of which depends upon the excited imagination of the patient. We see epilepsy, catalepsy, hysteria, chorea, and other diseases simulated during somnambulism, and even sudden death, caused by mere mental emotion, hope, fear, anger, &c. The student of medicine can at first scarcely read a graphic description of a disease without experiencing in imagination all the symptoms.

The force of imitation, in causing diseases, is also notorious, and is especially operative in childhood, and in persons of a nervous temperament. This sympathetic tendency is shown in inducing coughing, gaping, hiccoughing, vomiting, and other spasmodic affections. Whole schools have been seized with convulsive diseases from witnessing the terrific grimaces and contortions of an epileptic. We often witness this strong instinctive tendency to imitation in the repetition of atrocious crimes which have excited great horror. Thus, in Paris, at one of the large hospitals, a patient committed suicide by hanging himself in a certain doorway. The same thing was several times repeated in the same place, until the governor of the hospital ordered the door to be closed up with masonry, and the crime was no longer perpetrated. On the other hand, there is no doubt that many of the surprising cures attributed to the tombs and prayers of saints and holy reliques, and amulets, and magical charms, were actually performed chiefly through the agency of the imagination. The same remark applies to Thomsonianism, homœopathy, and empiricism in every form. The question in many of these cases is not so much as to the facts of the cure as their mode of production or causes.

From what has been said of somnambulism, it would appear that it consists essentially in lesion of function of the great nervous centres. There is a strong affinity between it and other common pathological conditions supposed to depend upon this cause, as lethargy, catalepsy, hysteria, &c., with which, indeed, it is sometimes complicated. When fairly considered, there is nothing more remarkable about this than other analogous pathological conditions. Many of the wonderful stories related respecting it are probably the results of accidental coincidences, self-delusion, or imposture. It is chiefly interesting from the light it throws on the physiology of the nervous system, and the etiology, pathology, and diagnosis of its diseases. Artificial somnambulism has been occasionally resorted to, therapeutically, to procure sleep, particularly in cases of great nervous excitement, where the use of the narcotic drugs was objectionable. Every well-informed physician must be aware of the great influence which the mind exerts over the physical condition of the organs, both in inducing and removing disease, and in his practice will be duly governed by this knowledge. But he will not forget that

self-respect and the dignity of the profession demand circumspection on these points. He will remember how readily mystery glides into charlatanry, and how apt the profession is to become degraded even by its semblance, when countenanced by respectable practitioners. Nor is this the only objection to resorting to these ceremonials. In the ecstatic state thus induced, there is certainly danger, particularly in nervous females and other excitable subjects, of causing convulsions, hysteria, epilepsy, &c., and that this practice may be otherwise grossly abused. It is to be regretted that an ultra spirit of refinement has extended its inroads within the dominions of science. It has manifested itself not only in the miracles of animal magnetism, but also, under the specious title of *Transcendentalism*, men of reputation and ability have ventured to practice a sort of learned trifling most dangerous to the interests of science. In this spirit we are called upon to listen to fair-drawn distinctions and obscure analogies; we are cautioned against limiting the laws of nature and narrowing the boundaries of science; and are warned against disbelieving alleged facts merely because they appear absurd and impossible. It is a subject of congratulation that the members of the profession in this country are little infected by this innovation, but are still inclined to follow the plain dictates of common sense and the spirit of the inductive philosophy in their scientific reasonings on these subjects.—*Ed.*]

OF DEATH.

The individual existence of all organized bodies is temporary; no animal escapes the hard necessity of dying; nor is man exempt from this. The particular history of each function shows that in the first periods of old age, and often before, the organs become deteriorated; that many completely cease to act; that others are absorbed and disappear; and, lastly, that in decrepitude, life is reduced to a few miserable remnants of the vital, and some of the nutritive functions in an imperfect state. In this condition, the most trifling external cause, the slightest blow or fall, is sufficient to arrest one of the functions indispensable to life, when death immediately follows, as the last degree in the destruction of the organs and functions. But a small number of persons die solely through the effects of age; it scarcely happens to one in a million; the remainder die at every period of life, by accidents and diseases. This great destruction of human life, by causes apparently accidental, appears to be provided for by nature, with as much care as she takes to secure the reproduction of the species.

THE END.

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